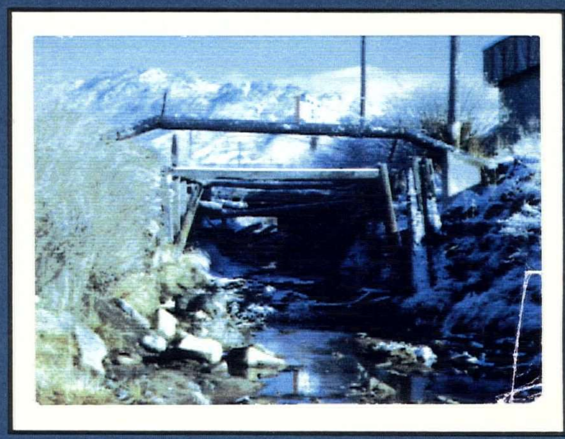
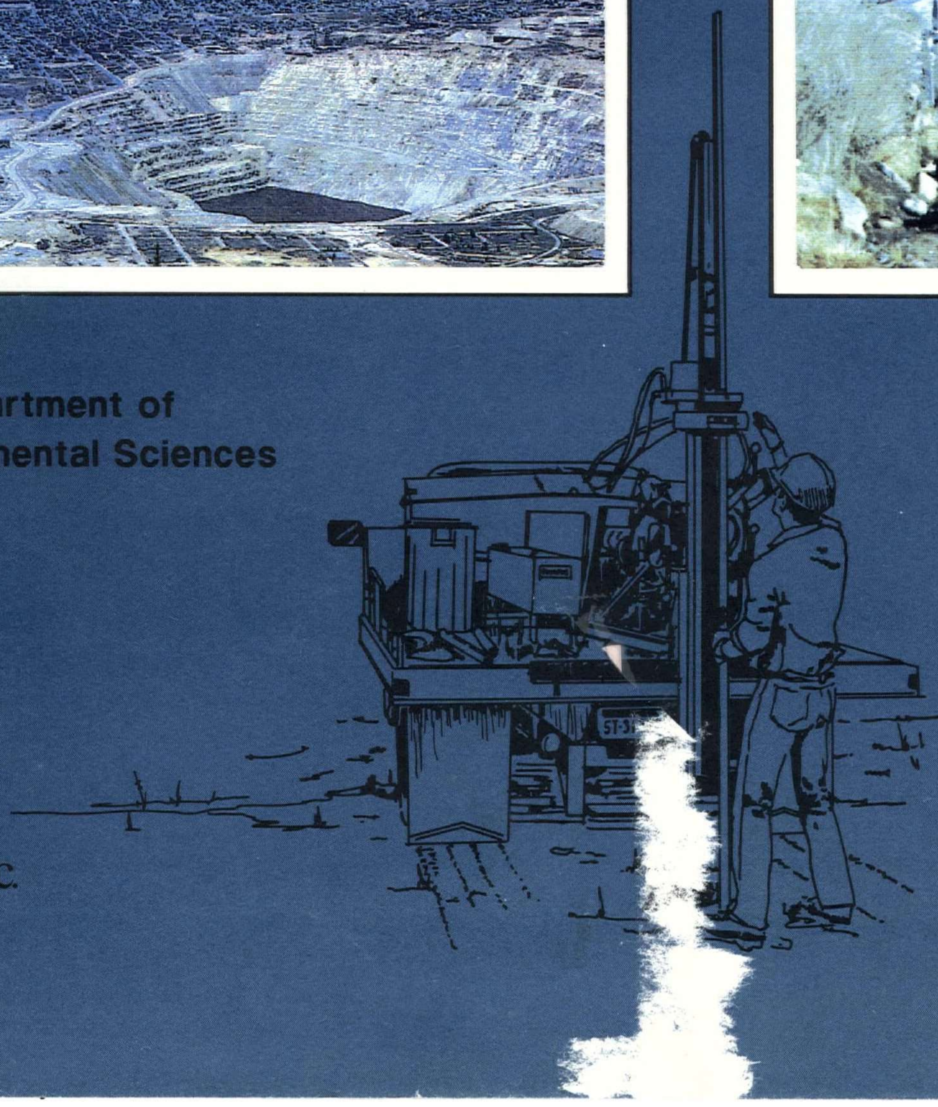
DRAFT FINAL
SILVER BOW CREEK CERCLA
PHASE II REMEDIAL INVESTIGATION
DATA SUMMARY

SILVER BOW COUNTY, MONTANA

AREA I OPERABLE UNIT





Montana Department of
Health and Environmental Sciences

VOLUME I:
REPORT

AUGUST 1990

Prepared by:
Chen-Northern, Inc.
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SILVER BOW CREEK CERCLA

PHASE II REMEDIAL INVESTIGATION DATA SUMMARY

AREA I OPERABLE UNIT

VOLUME I: TEXT

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EXECUTIVE SUMMARY

This report presents and summarizes results of environmental sampling completed during the Phase II Remedial Investigation at the Area I Operable Unit in and near Butte, Montana. The Area I Operable Unit is part of the larger Silver Bow Creek CERCLA (Superfund) site; the site was designated as an operable unit because types of contaminants and pathways of contaminant movement at the site are consistent and are somewhat unique with respect to surrounding areas.

Data produced during the Phase II Remedial Investigation supplement data generated during the Phase I Remedial Investigation at the site (MultiTech, 1987). The Phase II Remedial Investigation was completed in Area I to fill data gaps identified for the site prior to completing future studies and public health and environmental assessments.

The primary contaminants of concern in the Area I Operable Unit are metals, particularly copper, zinc, arsenic, cadmium, and lead. The primary pathways of contaminant movement in Area I include windborne transport, surface water runoff, infiltration of surface runoff into underlying groundwater systems, and groundwater movement to receiving surface water systems. The focus of this investigation was on identifying and characterizing sources of metals contaminants in the operable unit and in evaluating pathways of contaminant movement. The primary receptors of site contamination in Area I include inhabitants of the City of Butte and the environment. No effort was made during this investigation to identify receptors to site contaminants or potential impacts to receptors; these types of evaluations will be made during the public health and environment assessments for the operable unit.

General objectives to completing the Area I Operable Unit Phase II Remedial Investigation were to evaluate the following:

- Areas that may be sources of windblown dust which are contaminated with metals;
- The approximate areal and vertical extent of soil contamination;
- The nature and approximate extent of groundwater contamination and the pathways of contaminant movement in the area's shallow groundwater system;
- The source of relatively deep (greater than 150 feet) groundwater contamination in the upper Metro Storm Drain area.
- The impact of high flow on contaminant transport in the surface water system; and,
- The occurrence of organic compounds in the area's surface water system.

Other objectives to the investigation were to collect data to provide a basis for further characterization of the impact of exposed tailings/contaminated soils located within the operable unit on public health and the environment. Acquisition of these soils data were necessary to support a public health and environmental assessment of the operable unit and to evaluate various remedial alternatives for the area during future studies.

Three types of field investigations were performed during the Area I Operable Unit Phase II Remedial Investigation to fulfill project objectives. These include studies of surface water, groundwater, and tailings/contaminated soils. A direct evaluation of air in the operable unit was not performed during this investigation; this type of evaluation will be performed at a later date in conjunction with a city-wide air study. A brief description of the three studies completed during this investigation and a summary of results follows.

Surface Water

The surface water study performed as part of the Phase II Remedial Investigation focused on characterizing surface water quality and metal loads during a snowmelt runoff event which occurred in Butte during March, 1989. Sampling was completed during this in-bank runoff event at various sites within and adjacent to Butte; collected samples were analyzed for a variety of inorganic and organic parameters. In addition, a baseflow sampling event was completed at selected sites in Area I during August, 1989; samples collected during this sampling event were analyzed for organic compounds only.

Snowmelt sampling was completed to supplement limited high flow water quality data collected in Area I during the Phase I Remedial Investigation (MultiTech, 1987). Acquisition of additional high flow data was necessary to further characterize source areas of metals contaminants and to provide a means of evaluating chemical changes in surface water quality during runoff conditions.

The purpose of sampling for organic compounds during both high and baseflow events in Area I was to: (1) determine if organic compounds are present in the surface water environment of Area I during varying flow regimes; and, (2) determine potential source areas of organic compounds in the Butte area if such compounds were measured.

Results of snowmelt runoff sampling completed during March, 1989 in Area I indicated the following:

- Numerous exceedances of both chronic and acute aquatic water quality criteria and both primary and secondary drinking water standards occurred at several sites sampled during the snowmelt runoff event. The most commonly exceeded aquatic water quality criteria at monitored stations were for total or acid soluble cadmium, lead, copper, and zinc. Primary drinking water standards for arsenic, cadmium, and lead were exceeded at several surface water stations sampled during the snowmelt event.

- Highest concentrations of total and acid soluble metals measured during the snowmelt runoff event generally occurred in water entering the Metro Storm Drain from the Weed Concentrator area and in runoff derived from the Colorado Tailings. Lowest metals concentrations were typically measured in discharge from Blacktail Creek and the Sewage Treatment Plant.

- Arsenic, lead, and iron were generally transported through the surface water system during the snowmelt runoff event in the total fraction. Cadmium in the system was generally in the dissolved form. Copper and zinc were primarily carried in the dissolved fraction in the upper reaches of the Metro Storm Drain and in the total fraction at downstream sampling sites in the lower Metro Storm Drain and Silver Bow Creek.

- The majority of total arsenic, cadmium, lead, copper, and zinc loading in Silver Bow Creek during the snowmelt runoff event was derived from the Metro Storm Drain. The primary iron loading contributor to Silver Bow Creek was Blacktail Creek.

- Organic compounds sampled during the snowmelt runoff event were generally at or below detection limits used in Routine Analytical Services analyses. Detected organic compounds primarily included pesticides; concentrations of identified pesticides were well below any established drinking water standards or health advisories.

Results of organic compound analyses for samples collected during the August, 1989 low flow sampling event were similar to those for the snowmelt runoff sampling event.

Groundwater

The groundwater study completed as part of the Area I Operable Unit Phase II Remedial Investigation consisted of several interrelated components. These included: (1) a surface geophysical survey; (2) installation of monitoring, pumping, and observation wells; (3) groundwater sampling; (4) aquifer testing; and, (5) water level monitoring. The focus of the groundwater investigation was to determine the nature and extent of metals contamination in the area's alluvial groundwater systems. In addition, the groundwater study provided data to better characterize pathways of groundwater movement within the operable unit.

The surface resistivity survey was performed to provide data for use in siting monitoring wells and to gain a general understanding of the depth to bedrock beneath unconsolidated deposits present in Area I. An additional purpose of the resistivity survey was to determine the location and thicknesses of suspected placer deposits along the Silver Bow Creek channel. Identification of such deposits was desirable in evaluating preferential pathways of groundwater movement.

Results of the surface resistivity survey indicated the following:

- Surface resistivity data were useful in identifying areas of shallow groundwater exhibiting high specific conductivity. This information was used to site monitoring wells at locations which would bracket the lateral extent of metals contaminated groundwater.

- Depth to bedrock in the Metro Storm Drain area is generally greater than 200 feet below surface. Depth to bedrock in the vicinity of the manganese stockpile area and the Colorado Tailings is typically less than 40 feet.

- Resistivity data and subsequent drilling activities did not identify any sizable areas of buried placer deposits.

Monitoring wells were installed at 28 locations in Area I during the Phase II Remedial Investigation. ARCO also installed several monitoring wells in the Butte Reduction Works and Colorado Tailings areas during the time the remedial investigation was performed. Paired wells (wells completed at different depths at the same location) were also installed at 14 of the 28 well sites within Area I during the Phase II Remedial Investigation. The purpose of the paired wells was to provide means of characterizing changes in groundwater quality and groundwater elevation with depth in the area's aquifers. Most shallow monitoring well completions in Area I were less than 15 feet below ground surface; deeper monitoring well completions were typically 40 to 60 feet below ground surface.

A relatively deep (268 foot) monitoring well was installed in the vicinity of the City-County shop complex near the upper end of the Metro Storm Drain. The purpose of this well was to determine the vertical extent of metals contamination identified at depth during the Phase I Remedial Investigation (MultiTech, 1987). Material samples collected at this site during borehole advancement were also analyzed to determine if metals contamination in deeper zones in the groundwater system were attributable to natural mineralization of sediments.

Information and data collected during drilling activities associated with monitoring well installation in Area I indicated the following:

- Site lithologies generally consist of fill material, waste rock, slag, and mine and mill tailings underlain by alternating sequences of sand, sand and gravel, silt, and clayey silt units. Correlation of individual lithologic units laterally is difficult.

- Observations made during drilling activities in Area I indicate that the relatively coarse sand and sand and gravel units generally yielded 15 to 20 gallons per minute (gpm). Finer grained units yielded less than 5 gpm during drilling.

- A relatively well sorted gravel unit was encountered at a depth of 210 feet below ground surface in the upper Metro Storm Drain area near the City-County shop complex. This 20 foot thick unit yielded greater than 100 gpm during borehole advancement.

- The uppermost water-bearing unit was generally encountered within 10 feet of the surface except in the upper Metro Storm Drain area where depth to water is 20 to 30 feet below surface. Where tailings were identified in the boreholes, groundwater was generally encountered within one to two feet below the base of the tailings.

Groundwater sampling events were completed during the Phase II Remedial Investigation during August and November, 1989. Sampled wells included monitoring wells installed during both the Phase I and Phase II Remedial Investigations, selected monitoring wells installed previously by ARCO and the Montana Bureau of Mines and Geology, and selected domestic wells. Sampled wells provided data with which to characterize metals contaminants both spatially and vertically throughout the study area. Collected samples were analyzed for dissolved metals, common ions, and nutrients.

Results of groundwater sampling completed during the Phase II Remedial Investigation indicated the following:

- There are three general source areas of metals-contaminated groundwater in Area I. These include the City-County shop complex area, the Butte Reduction Works tailings impoundments-Butte Sewage Treatment Plant area, and the Colorado Tailings. The primary metal contaminants in these areas are copper, zinc, cadmium, lead, arsenic, iron, and manganese. Concentrations of metals in these areas are two to four orders of magnitude higher than in areas located upgradient and cross-gradient.

- Metal concentrations generally decrease with increasing distance from the three general source areas.

- One or more exceedances of primary drinking water standards for arsenic, cadmium, lead, nitrate + nitrite as nitrogen, and fluoride were measured in groundwater samples collected from 37 monitoring wells and two domestic wells. The total area of the alluvial groundwater system within Area I which exceeds primary drinking water standards is about 400 acres.

- Metals concentrations typically decrease with depth in the area's groundwater systems. The depth to which groundwater exceeds primary drinking water standards in the upper Metro Storm Drain area is approximately 150 feet below ground surface; this depth decreases to about 50 to 60 feet below ground surface in the vicinity of Kaw Avenue near the lower end of the Metro Storm Drain.

X-ray diffraction data for material samples collected at depth in the upper Metro Storm Drain area indicate metals-contaminated groundwater is not the result of natural mineralization of the host sediments.

Metals concentrations also decrease with depth rapidly in the vicinity of the Butte Reduction Works tailings impoundments and the Butte Sewage Treatment Plant. However, metals concentrations appear to increase with depth into the underlying bedrock groundwater system in the vicinity of the Colorado Tailings; a lower bound to metals contamination in groundwater beneath the Colorado Tailings was not determined during this study.

- A calcium-bicarbonate type water is generally associated with groundwater which is not impacted by metals contaminants. Groundwater which contains relatively high concentrations of metals is generally a calcium-sulfate type water.

Aquifer testing completed during the Area I Operable Unit Phase II Remedial Investigation consisted of two components. Slug testing was completed in 46 monitoring wells throughout the study area to gain a general understanding of the relative differences in permeability at various depths in the groundwater system. In addition, long-term pumping tests were performed at four locations within the study area to provide more definitive data regarding hydraulic characteristics of the shallow groundwater system.

Results of these aquifer tests indicated the following:

- The shallow groundwater system in the upper Metro Storm Drain area near the City-County shop complex exhibits low hydraulic conductivity, on the order of 2.5 ft/day. Phase I Remedial Investigation aquifer test data (MultiTech, 1987) suggest that this relatively low hydraulic conductivity environment extends to about 200 feet below ground surface in this area.

- The shallow groundwater system in the middle and lower reaches of the Metro Storm Drain area exhibits relatively higher hydraulic conductivities than the upper Metro Storm Drain area. Calculated hydraulic conductivities in this portion of the study area are on the order of 15 ft./day.

- The shallow groundwater system in the vicinity of the historic Butte Reduction Works tailings impoundments displayed the highest hydraulic conductivities measured in Area I. Calculated hydraulic conductivities in this area were about 150 ft./day.

- Calculated hydraulic conductivities for the shallow groundwater system underlying the Colorado Tailings were relatively low, on the order of 15 to 20 ft./day.

Water level data collected during the Phase II Remedial Investigation were used to evaluate groundwater flow directions and horizontal and vertical groundwater gradients. These data indicate the following:

- The shallow alluvial groundwater system in the vicinity of the Weed Concentrator and City-County shop complex is relatively flat. A groundwater divide is present in the alluvial groundwater system in the vicinity of Continental Drive. Groundwater north of this divide moves toward the Berkeley Pit; groundwater south of this divide moves to the southwest, parallel to the Metro Storm Drain.

- Recharge to the alluvial groundwater system in Area I is derived from the east, south of the Berkeley Pit, from the Blacktail Creek alluvial system, and from groundwater systems entering from Butte Hill and the foothills south of the Colorado Tailings.

- Lateral groundwater gradients in the alluvium in Area I range from about 0.3% in the middle reaches of the Metro Storm Drain area to about 0.1% in the vicinity of the Butte Reduction Works area.

- Groundwater movement is generally parallel to and toward the Metro Storm Drain and Silver Bow Creek. Data indicate both the Metro Storm Drain and Silver Bow Creek are gaining water from groundwater inflow throughout the study area with the exception of the reach of the Metro Storm Drain above Harrison Avenue.

- Vertical groundwater movement is downward in the upper Metro Storm Drain area and in the area south of the Colorado Tailings at gradients ranging from 2 to 9%. Groundwater discharge areas were identified in the lower Metro Storm Drain area and near the west end of the Colorado Tailings. Upward vertical gradients in these areas ranged from 1.5 to 8%. There was no significant trend to vertical groundwater gradients in the portion of the study area between Montana Street and the Butte Sewage Treatment Plant.

Soils

Soils investigations completed during the Area I Operable Unit Phase II Remedial Investigation focused on identifying and sampling the various types of materials present within the study area. No efforts were made to directly characterize soils in residential areas within or adjacent to the Area I study area; this type of study is being completed by the USEPA throughout Butte. Soils data collected during the Phase II Remedial Investigation in Area I, however, will be directly applicable to USEPA studies in Butte.

Three general activities were conducted as part of the soils study in Area I. These consisted of a soils mapping effort, sampling of dispersed tailings and contaminated soils, and sampling and characterization of impounded tailing deposits. The soils mapping task was completed to identify and describe the various material types present within the study area. The mapping effort provided a basis from which soils/tailings sampling sites were selected.

The dispersed tailings/contaminated soils and impounded tailings sampling efforts were completed to provide chemical and physical data for the various map units identified during the soils mapping effort. In addition, approximate volumes of contaminated material were calculated using these data. Data generated during the soils investigations will be used to evaluate risk to public health and the environment and will also be used to support evaluations of cleanup alternatives.

Data acquired during the soils and tailings investigations completed during the Area I Operable Unit Phase II Remedial Investigation indicate the following:

- Site soils consist of a variety of material types which can be differentiated primarily on the basis of texture, color, and location.

- Material types present in Area I include both natural soils and sediments and man-emplaced materials. Natural soils and sediments include upland soils and colluvial sediments, alluvial sands and gravels, and floodplain peat and clay deposits. Man-emplaced materials include landfill materials, waste rock fill, mine and mill tailings placed in impounded facilities, low grade ore and sulfidic materials used for railroad fill, and flood deposited mixtures of tailings and alluvium.

- Subsurface materials are generally intermixed; the lateral variability in material types could not be accurately mapped in the subsurface with the level of subsurface information gathered during this investigation.

- Three material types are the primary sources of metals in Area I. These include exposed tailings (material unit 1), covered tailings (material unit 2), and mixed tailings and alluvium (material unit 4). These material units were found in greatest abundance in the vicinity of the historic Parrott Smelter at the upper end of the Metro Storm Drain, in the vicinity of the historic Butte Reduction Works tailing impoundments, and in the Colorado Tailings area.

- Other materials which exhibited relatively high metals concentrations included railroad ballast beneath an abandoned line in the vicinity of the manganese stockpile area and tailing deposits located beneath slag walls in the manganese stockpile area.

- Finer grained material associated with surface (0 to 1 inch) samples collected from exposed areas within the operable unit exhibited relatively higher metals concentrations than coarser fractions.

- Metals, particularly copper and zinc, in exposed tailings material solubilize in water.

- Sampling for organic compounds completed in Area I proximal to the Montana Pole Superfund site produced data which indicated petroleum hydrocarbon contamination (primarily toluenes) was present in a subsurface sample obtained near the product recovery trench at the site. The data indicated that the extent of petroleum hydrocarbons in the soils in this portion of Area I is limited and that the source of the compounds is the Montana Pole site. Samples for organic compound analysis were not collected elsewhere in Area I during this investigation.

- Several samples collected for EP Toxicity analyses exceeded maximum concentrations of contaminants defined by the USEPA for lead and cadmium.

Conceptual Description of Site Conditions

Data gathered during the Phase II Remedial Investigation and other data available for the Butte area provide a reasonable basis from which problems in Area I can be identified and from which general concepts can be developed regarding contaminant sources, pathways, and receptors in the operable unit. Contaminants in Area I are primarily associated with various metals parameters including copper, zinc, lead, arsenic, cadmium, and iron. Available data suggest there is little evidence of organic contamination in Area I with the exception of hydrocarbon-related compounds adjacent to the Montana Pole Superfund site. It is probable that the presence of these compounds in this portion of the study area is associated with source areas already identified at the Montana Pole site.

Contaminant Source Areas

The primary source areas of metals contaminants in Area I include the historic Parrott Smelter tailings and waste deposits, the historic Butte Reduction Works tailing impoundments and associated slag deposits, and the Colorado Tailings. The majority of source material (tailings) associated with the historic Parrott Smelter has been covered with fill material to facilitate commercial and residential construction. Because of this, the source material in this portion of the study area is present at depths ranging from 10 to 30 feet below surface and ranges in thickness from a few inches to over seven feet. The approximate volume of metals-enriched material in the vicinity of the Parrott Tailings is 650,000 cubic yards. For purposes of this report, "metals-enriched" is defined as that material which exhibits metals concentrations one to two orders of magnitude higher than adjacent or subjacent material.

Sources of metals-enriched material in the Butte Reduction Works and Colorado Tailings areas are at and near the surface. Thicknesses of metals-enriched material in the Butte Reduction Works and Colorado Tailings are about 10-15 feet and 6-8 feet, respectively. The estimated volume of metals-enriched material associated with the Butte Reduction Works-Sewage Treatment Plant area within Area I is 1.6 million cubic yards of which approximately 430,000 cubic yards are either tailings or mixed alluvium-tailings material and 130,000 cubic yards are associated with railroad ballast. This volume estimate does not include slag walls or stockpiles of manganese present in the area. The volume of metals-enriched material in the Colorado Tailings area is about 600,000 cubic yards of which approximately 230,000 cubic yards are tailings material.

Numerous other metals-enriched areas are present within Area I between the major source areas. Several factors appear to affect the tendency for metals to migrate from a particular metals-enriched sediment deposit in Area I to a receptor or another environmental media. These include factors such as whether the metals-enriched deposit is exposed or buried, whether groundwater intercepts the deposit, the location of the deposit with respect to surface water courses, and the intensity of vegetation overlying the deposit. Most metals-enriched areas outside of the three primary source areas in Area I are in locations which appear to minimize the potential of metals migration with respect to the foregoing factors.

Contaminant Pathways

Metals contaminants in Area I are transported in the environment by three primary mechanisms. These include air, surface runoff, and groundwater. The air pathway was not directly evaluated during the Phase II Remedial Investigation; this pathway was evaluated indirectly through analysis of metals by various grain sizes in material which is subject to airborne transport. These data indicated that finer grained fractions (< 200 mesh) of sampled surface (0 to 1 inch) soil samples generally contained higher metals concentrations than coarser grained fractions. Actual concentrations of metals in the fine-grained fractions were variable between soil map units.

Surface runoff was evaluated during both the Phase I and Phase II Remedial Investigations. These data indicate that the majority of metals transported during in-bank runoff events are derived from source areas outside of Area I, primarily on Butte Hill. A component of metals in surface water during surface runoff events, however, is derived from within Area I. Surface soils data collected during the Phase II Remedial Investigation suggest that certain locations within Area I contain metals in surface soils and tailings which readily solubilize in water.

Groundwater is an important pathway for transporting metals to surface water in Area I and is probably the primary contributor of metals to Silver Bow Creek during low flow and baseflow conditions. A downward vertical gradient in the groundwater system appears to move metals-contaminated groundwater from upper portions of the groundwater system to as deep as approximately 150 feet below ground surface in the vicinity of the Parrott

Tailings. X-ray diffraction analyses of material samples collected at these depths indicate that the material hosting this metals-laden groundwater is not naturally mineralized and is therefore not a source for elevated metals concentrations in groundwater occurring at these depths. Downward groundwater gradients in this area may be caused by a 20-foot thick higher permeability sand and gravel unit identified at a depth of approximately 210 feet below ground surface or it may be related to a dewatered portion of the underlying bedrock system caused by historical pumping from the Berkeley Pit area.

Groundwater in the vicinity of the Parrott Tailings also moves laterally, parallel to the Metro Storm Drain. In the vicinity of Harrison Avenue, the base of the Metro Storm Drain intercepts the shallow groundwater system causing surface flow in the normally dry channel. An upward groundwater gradient measured in the lower Metro Storm Drain area also serves to provide additional flow to the Metro Storm Drain.

Groundwater movement in the vicinity of the Butte Reduction Works and Sewage Treatment Plant area is generally horizontal. Contaminated groundwater in this vicinity moves laterally into Silver Bow Creek.

Shallow groundwater in the Colorado Tailings area appears to move from the southeast to the northwest and eventually enters Silver Bow Creek. A relatively strong downward component to groundwater movement is evident near the southern edge of the Colorado Tailings and to the east of the deposit. This may cause a component of the groundwater system to move shallow contaminants to depth and into the underlying bedrock system. An upward groundwater gradient occurs at the west edge of the Colorado Tailings and to the west of the deposit. This situation is likely caused by a bedrock constriction located in this area which decreases the thickness of the alluvial aquifer. This phenomenon probably moves metal contaminants at depth upward and into Silver Bow Creek.

Site Problems

General problems identified in Area I during the remedial investigation include the following:

- Large areas of surface contamination, comprised of tailings and contaminated soils, are present within the boundaries of the operable unit. These materials contain elevated levels of several metals and, in some cases, are sparsely vegetated or barren of vegetation. The most prominent exposed area within Area I is the Colorado Tailings. Exposed tailings and contaminated soils are available for human and animal exposure. These exposed areas are also susceptible to erosion and entrainment during snowmelt and precipitation-induced runoff events. Because large expanses of exposed tailings and contaminated soils are located within the floodplain of Silver Bow Creek, the material is also subject to entrainment during major flood events. The eventual impact of runoff from these areas due to snowmelt, precipitation, or floods is realized in degraded water quality and aggradation in receiving surface water courses.

- Exceedances of both chronic and acute aquatic water quality standards are common in both the Metro Storm Drain and Silver Bow Creek. During higher flow events caused by snowmelt or precipitation runoff input to surface water courses, exceedances of primary and secondary drinking water standards in Silver Bow Creek are also commonplace.

  Sources of chronic metals contamination in the Metro Storm Drain and Silver Bow Creek are derived primarily from inflow of contaminated groundwater. Acute metals contamination in the Metro Storm Drain and Silver Bow Creek is realized from surface runoff. The primary sources of metals contamination to surface runoff are located largely outside of Area I on Butte Hill.

- Metals are transported out of Area I in several forms, primarily by Silver Bow Creek, and, to a lesser extent, by groundwater. These transported metals deleteriously affect downstream water quality.

- A large volume of subsurface material also containing elevated metals concentrations is present within the operable unit. Metals concentrations in this material is one to two orders of magnitude higher than concentrations measured in adjacent and subjacent materials. These materials represent sources of metals contamination to groundwater through precipitation infiltration and through contact with groundwater caused by fluctuations in groundwater elevation. The most prominent source areas which impact groundwater resources in Area I include the historic Parrott Smelter and associated tailing and slag waste deposits, the historic Butte Reduction Works tailing impoundments and associated slag deposits beneath the Butte Sewage Treatment Plant, and the Colorado Tailings.

  Metals-contaminated groundwater moves dynamically within Area I but eventually discharges into surface water courses including the Metro Storm Drain and Silver Bow Creek. Groundwater impacts on receiving surface water courses becomes most prominent during low flow and baseflow conditions in the Metro Storm Drain and Silver Bow Creek.

- A large portion of the alluvial groundwater system in Area I contains water which exceeds both primary and secondary drinking water standards. This resource is currently unusable as a potable water supply.

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1.0 INTRODUCTION

This data summary report presents and summarizes environmental data collected during the Phase II Remedial Investigation (RI) at the Area I Operable Unit. The Area I Operable Unit is a portion of the larger Silver Bow Creek Superfund site, which was placed on the Superfund National Priorities List in September, 1983. Area I is the second operable unit to undergo a Phase II RI in the Silver Bow Creek Superfund site. The Warm Springs Ponds Phase II RI and Feasibility Study (FS) were completed during 1989 (CH2M HILL, 1989a and 1989b).

MultiTech (1987) reports results of Phase I RI activities at the Silver Bow Creek CERCLA site. A portion of the investigative activities performed during that study were completed within the Area I Operable Unit. Following completion of the Phase I RI, several gaps were identified in the data needed to fully characterize contaminant sources and pathways of contaminant movement in the Area I Operable Unit (CH2M HILL, 1989c).

Investigations conducted at the Area I Operable Unit during the Phase II RI included sampling and analysis of surface water, groundwater, and contaminated soils and tailings. The primary contaminants of concern within the operable unit are heavy metals, including copper, zinc, cadmium, arsenic, lead, and iron.

This data summary report is arranged by environmental media investigated during the Phase II RI. A brief description of field activities and data collection methods used during the various investigations is presented first within each section of the report, followed by a summary of results. These sections are followed by an evaluation of the quality of data generated during the study and a summary of contaminant sources, pathways, and receptors in Area I.

Exhaustive interpretations of collected data are not included in this document. More complete analyses will be completed, as necessary, during future studies of the operable unit. Various data bases created during this study and other pertinent information are presented in appendices which accompany this report (Volume II).

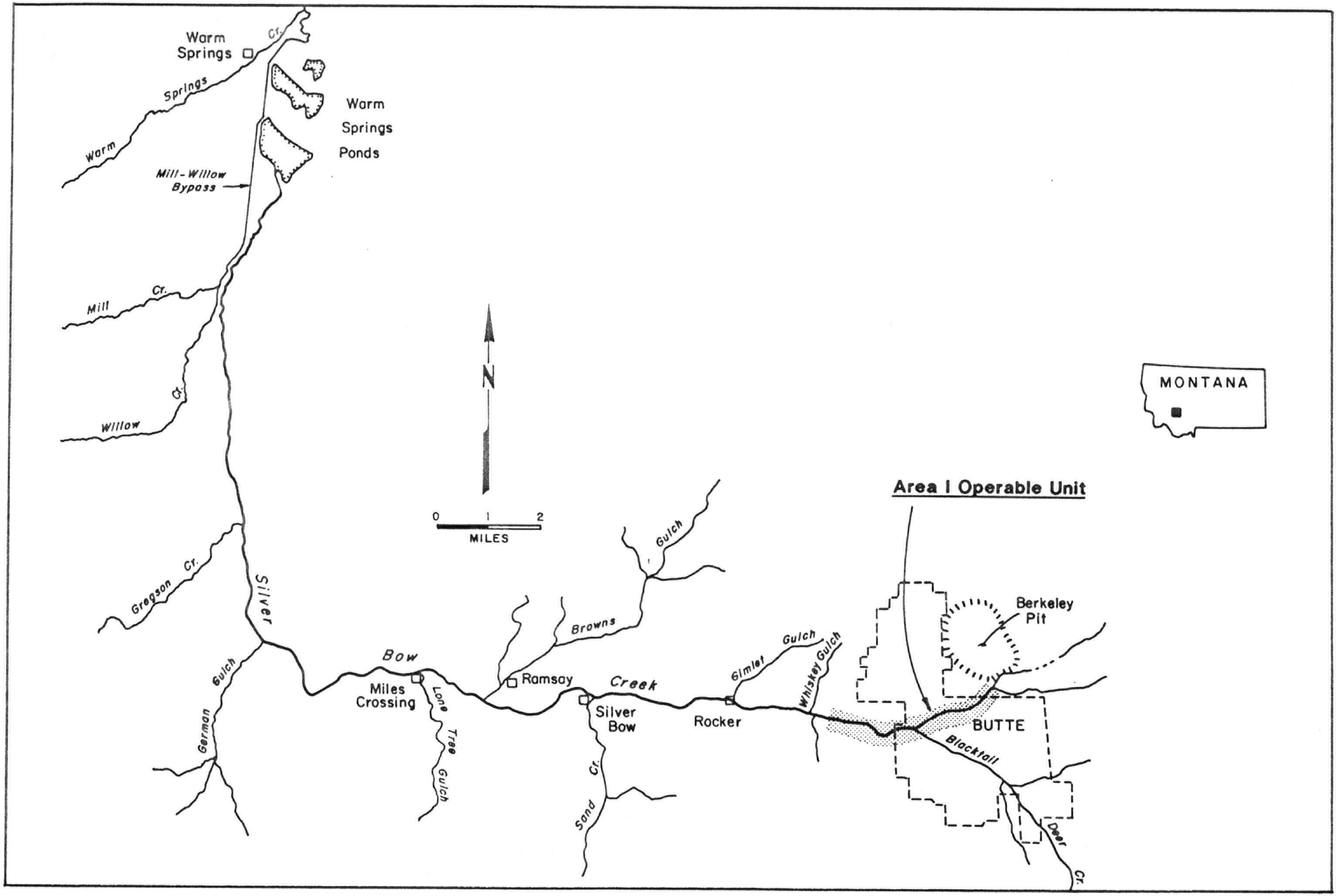
Methods used to collect environmental samples during the Area I Operable Unit Phase II RI are described in the project work plan and the project sampling and analysis plan (CH2M HILL, 1989c, 1989d). Changes to these plans and the consequences of those changes are described herein.

1.1 PROJECT BACKGROUND

Area I is a designation that describes a specific portion of the Silver Bow Creek CERCLA site. Area I is located primarily within and adjacent to urbanized areas of the city of Butte, Montana (Figure 1-1). The Area I Operable Unit study area generally parallels the Butte-Metro Storm Drain from below the Weed Concentrator to its mouth and the reach of Silver Bow Creek from below the confluence of Blacktail Creek and the Metro Storm Drain to below the Colorado Tailings (Figure 1-2).

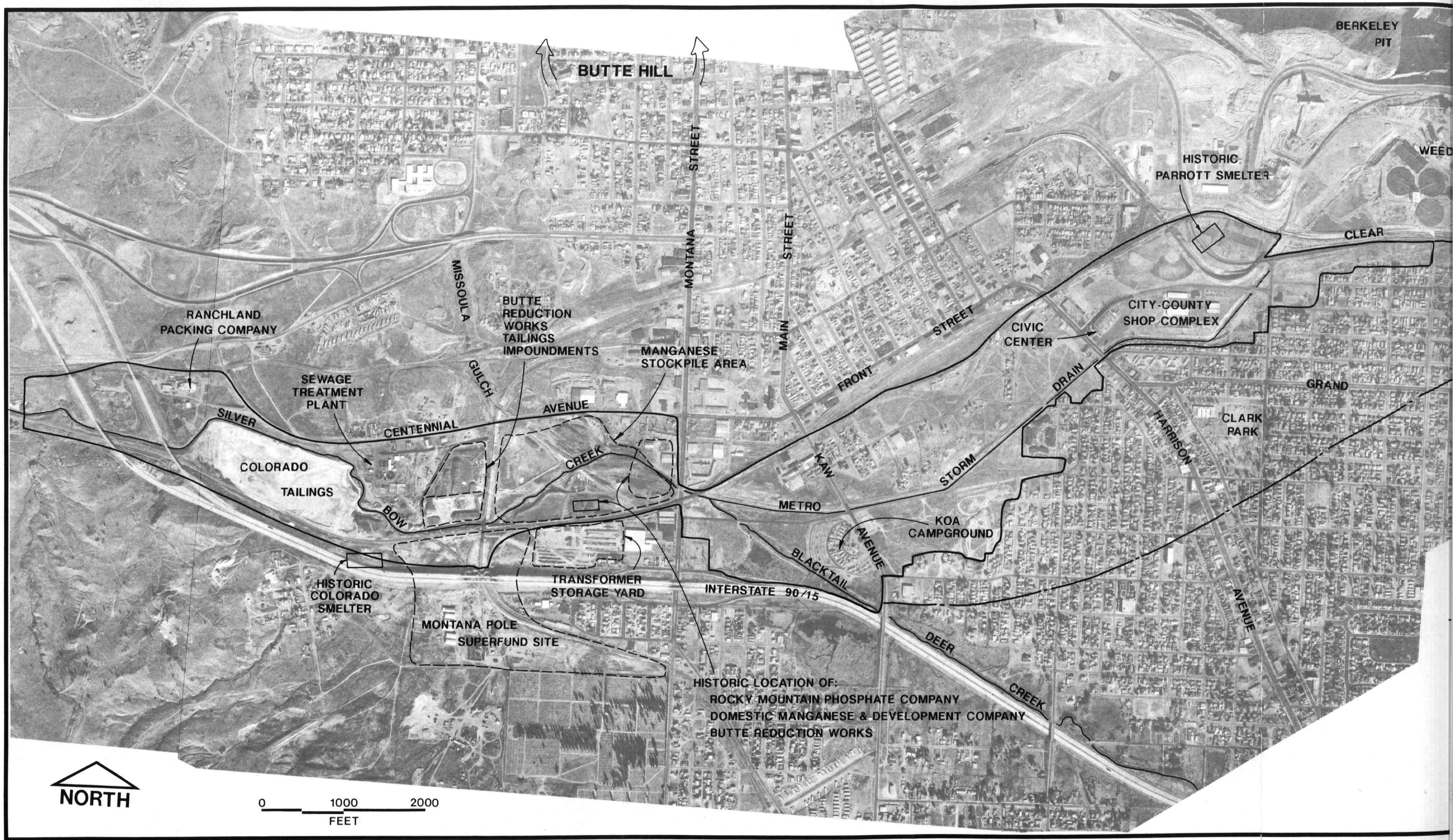
Silver Bow Creek and contiguous portions of the upper Clark Fork River were listed as a Superfund site in September, 1983 by the U.S. Environmental Protection Agency (EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The site currently extends from Butte to Milltown, Montana, some 140 river miles. The Solid and Hazardous Waste Bureau of the Montana Department of Health and Environmental Sciences (MDHES) formerly administered EPA appropriations and directed efforts to conduct remedial investigations associated with the site. Currently, EPA is administering all Superfund activities in the Butte area. Area I was designated as an operable unit because the contaminant sources and pathways of contaminant movement within the area are consistent and are somewhat unique with respect to adjacent areas.

The Montana Pole and Treating Company Superfund site is adjacent to the Area I Operable Unit. The Area I Operable Unit is also surrounded on three sides by the Butte Addition to the Silver Bow Creek Superfund site which includes Butte Hill, the Berkeley Pit, the Clark-Timber Butte Tailings, and areas hosting mine flooding in the west camp of Butte near the Travona mine shaft. Efforts were made during the Area I Phase II RI to coordinate field activities among the various studies to maximize data usage between sites, prevent overlap of study efforts, and minimize redundancy in gathered data.



Silver Bow Creek CERCLA Site Index Map

FIGURE 1-1



BUTTE HILL
BERKELEY PIT
WEED
HISTORIC PARROTT SMELTER
CLEAR
CITY-COUNTY SHOP COMPLEX
CIVIC CENTER
GRAND
CLARK PARK
HARRISON
AVENUE
DRAIN
STORM
FRONT
STREET
MONTANA
STREET
MAIN
STREET
MISSOULA
GULCH
BUTTE REDUCTION WORKS TAILINGS IMPOUNDMENTS
MANGANESE STOCKPILE AREA
RANCHLAND PACKING COMPANY
SEWAGE TREATMENT PLANT
SILVER
BOW
CREEK
CENTENNIAL
AVENUE
COLORADO TAILINGS
METRO
KAW
AVENUE
KOA CAMPGROUND
BLACKTAIL
DEER
CREEK
INTERSTATE 90/15
HISTORIC COLORADO SMELTER
TRANSFORMER STORAGE YARD
MONTANA POLE SUPERFUND SITE
HISTORIC LOCATION OF:
ROCKY MOUNTAIN PHOSPHATE COMPANY
DOMESTIC MANGANESE & DEVELOPMENT COMPANY
BUTTE REDUCTION WORKS
NORTH
0
1000
2000
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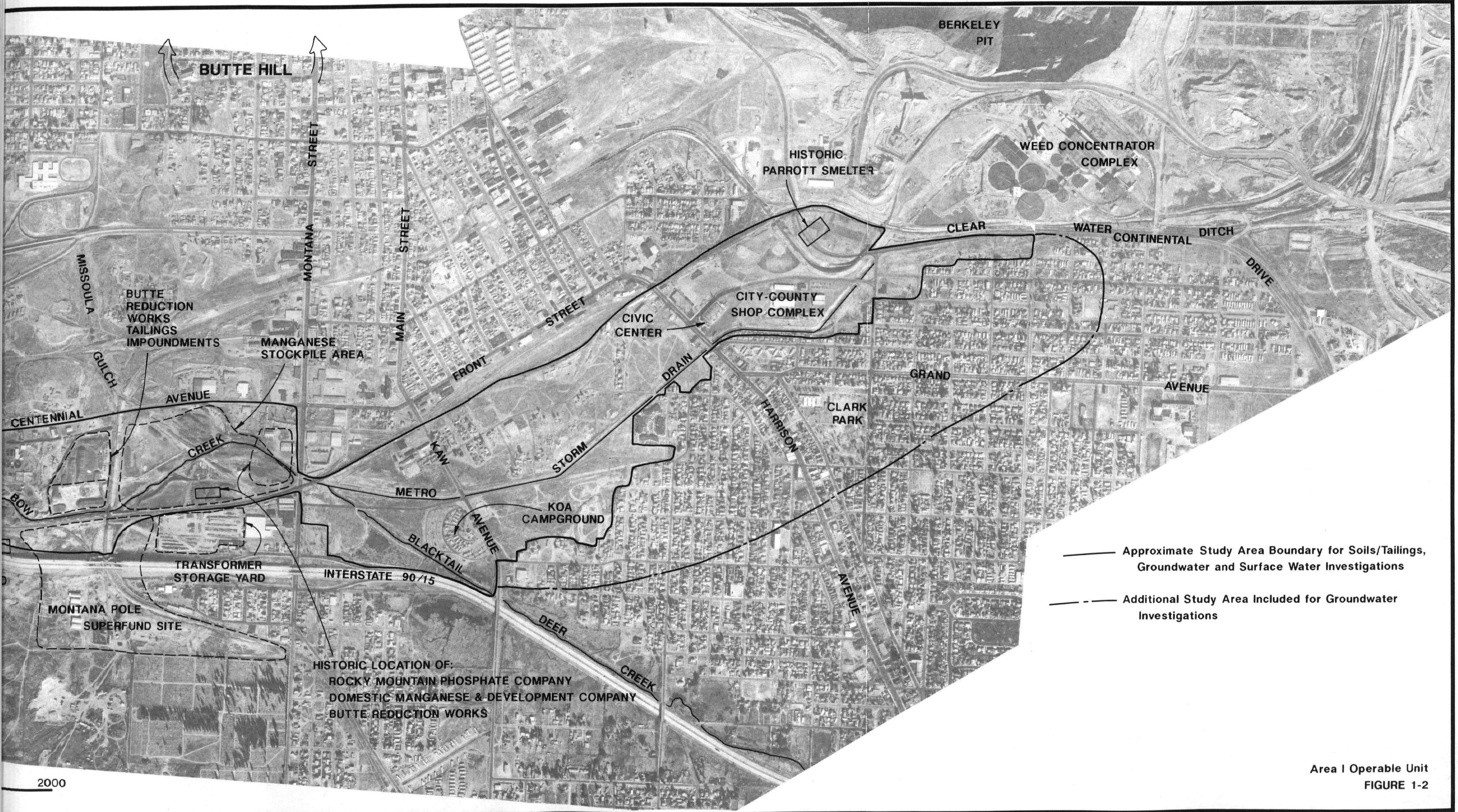


Approximate Study Area Boundary for Soils/Tailings, Groundwater and Surface Water Investigations

Additional Study Area Included for Groundwater Investigations

Area I Operable Unit
FIGURE 1-2

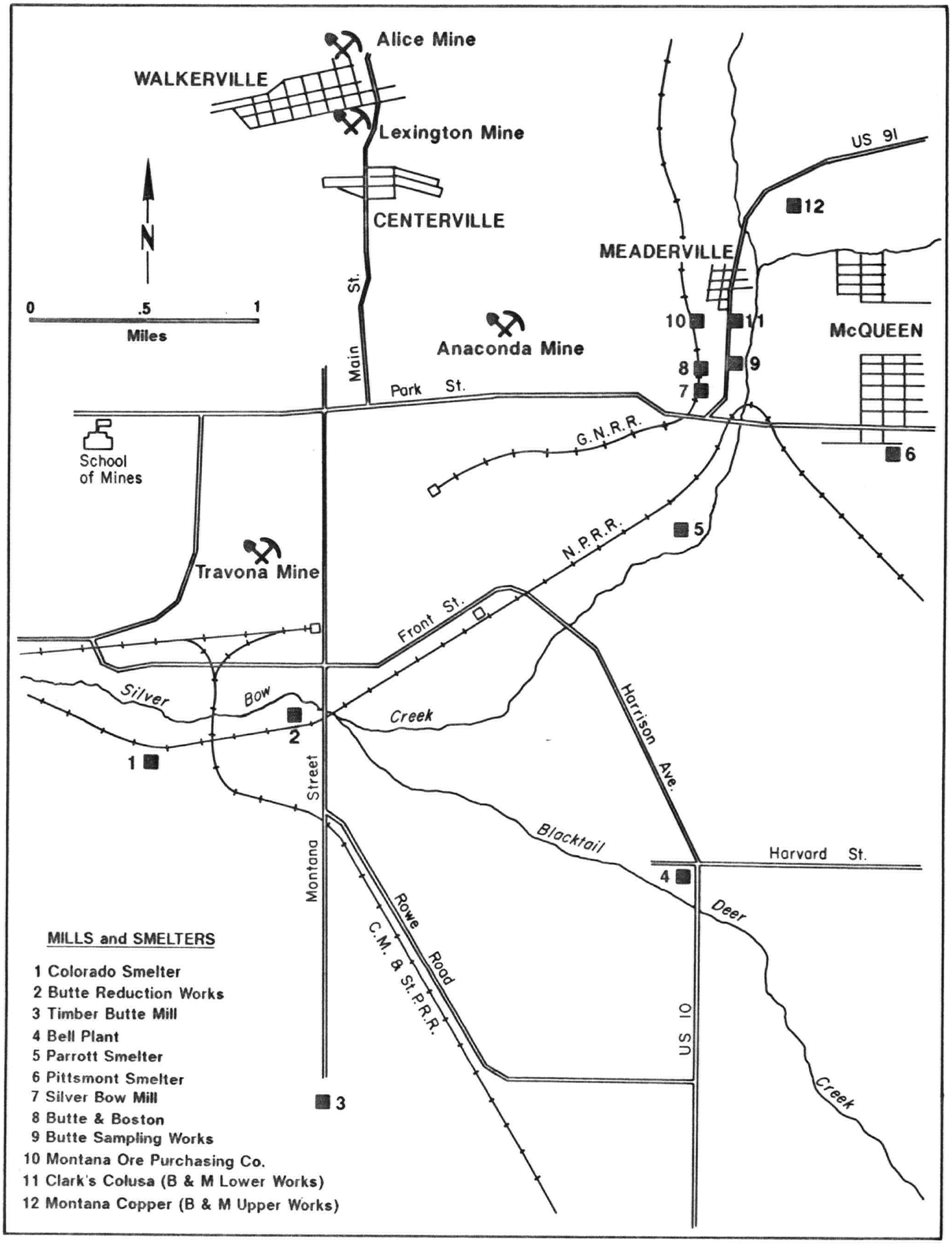
The Phase I Remedial Investigation completed for the Silver Bow Creek CERCLA site (MultiTech, 1987) preliminarily characterized environmental conditions in the Area I Operable Unit. A summary of data derived from the Phase I investigation and other historic data for the Area I Operable Unit are presented in the Area I Phase II RI work plan (CH2M HILL, 1989c). The work plan also describes known and suspected contaminant sources, probable transport pathways, specific data gaps, and methods to fill identified data gaps.

1.2 GENERAL SITE HISTORY

The history of man's activities along Silver Bow Creek within and adjacent to the Area I Operable Unit is long and varied. The first record of any disturbance of the stream's natural channel is in 1864 when placer mining commenced along Silver Bow Creek (Freeman, 1900; Meinzer, 1914; Smith, 1952). Placer mining techniques were used to extract low-grade gold deposits along Silver Bow Creek and its tributaries, particularly along Missoula Gulch (Figure 1-2). The majority of placer operations in the area had ceased by 1869, although a small contingent of placer miners continued placering local streams after this date.

Concurrent with placer mining along Silver Bow Creek, hard rock mining started on mineralized veins outcropping on Butte Hill, north of Silver Bow Creek. Several small smelters/concentrators and a wet-process quartz mill (Davis Mill) were built from 1866 to 1868 along Silver Bow Creek to process ore (Smith, 1952). Although some copper and silver were produced, all facilities were closed by 1869. Apparently, little mining activity occurred in the Butte area from 1869-1874.

William Farlin restaked some mining claims on the Butte Hill in 1875 as a result of favorable silver ore assays found in the area (Smith, 1952). This rejuvenated mining activity in Butte and by 1878 several small smelters were operating in the area. By 1881, Butte had become one of the nation's major mining centers; the district attained national dominance in copper mining by the mid-1890s and international prominence by the turn of the century. Between 1879 and 1885, at least six major smelters were built along Silver Bow Creek from Meaderville to Williamsburg (HRA, 1983; Smith, 1952; Meinzer, 1914; Freeman, 1900). Locations of these smelters are shown on Figure 1-3. A smelter was also constructed at the



from: Smith (1952)
rev: USGS (1903)

Early Reduction Plants in Butte

FIGURE 1-3

new town of Anaconda in 1884 by Marcus Daly, one of the founders of the Anaconda Copper Mining Company (Smith, 1952).

The major smelters constructed along Silver Bow Creek operated nearly continuously until 1910 (HRA, 1983). By 1910, Anaconda Copper Mining Company had purchased and closed all but one of the major concentrators/smelters (the Pittsmont) located adjacent to Silver Bow Creek; most of the ore was shipped to the smelter in Anaconda for processing. This practice continued until 1980 when the smelter in Anaconda was closed. The Pittsmont Smelter operated until 1930.

The Timber Butte Mill, located south of Silver Bow Creek (Figure 1-3) operated until approximately 1930. Tailings from the Timber Butte Mill, Butte and Superior, and East Butte concentrators were sluiced in various amounts to tributaries of Silver Bow Creek until at least 1918 (MultiTech, 1987). Milling and smelting operations adjacent to Silver Bow Creek generated an estimated total of 10 million tons of waste from 1878-1925 (MultiTech, 1987).

Large-scale underground mining continued in Butte during the early- to mid-1900's. In 1955, Anaconda Copper Mining Company commenced open-pit mining at the Berkeley Pit. Low-grade copper ore mined from this source was processed at the Weed Concentrator in Butte, constructed in 1963.

Silver Bow Creek continued to receive raw mining and milling wastes until 1972, when a treatment plant was added to the Weed Concentrator (Spindler, 1976). In 1977, Anaconda Copper Mining Company was merged with the Atlantic Richfield Company (ARCO). ARCO closed all underground mining operations in Butte in 1980 because of a depressed copper market. ARCO likewise closed the Berkeley Pit in 1982 and the adjacent East Berkeley Pit in 1983. The underground mines beneath Butte and the Berkeley Pit were allowed to flood and water levels in the area are currently rising in response to the cessation of pumping.

In 1986, Montana Resources Inc. (MRI) purchased Anaconda's Butte Operations (including the Berkeley Pit, East Berkeley Pit, Continental East Pit, and the Yankee Doodle Tailings Ponds). In 1989, American Smelting and Refining Company (ASARCO) purchased minority ownership of MRI's Butte operations. MRI and ASARCO are currently mining copper-ore from the East Berkeley Pit and are processing mined ore at the Weed Concentrator. There are currently no direct surface discharges from MRI's operation to Silver Bow Creek.

1.3 HISTORY OF SITE CONTAMINATION

Area I and adjacent areas have historically been a center of mining, milling, and smelting activity, primarily involving the Parrott Smelter and other mills and smelters in the upper portion of the study area near the Metro Storm Drain, and the Butte Reduction Works Mill and the Colorado Smelter in the lower portions of the study area (Figure 1-2). The upper portion of the study area lies within residential and commercial areas of the city of Butte. The Metro Storm Drain was constructed through the area during the 1930's to provide a means of transporting storm runoff out of Butte. The Metro Storm Drain generally follows the historic course of Silver Bow Creek. Wastes from several mills and from mining activities in the general vicinity of the present day Weed Concentrator were deposited directly into historic Silver Bow Creek or were contained in tailings ponds constructed adjacent to the stream.

It is probable that a portion of wastes released to surface water courses in the Butte area was transported out of Butte by Silver Bow Creek. However, a sizable volume of wastes remained within and adjacent to the historic stream channel and within constructed tailing ponds. Wastes remaining in the area have largely been covered or filled over and thus are not readily visible at the surface today. Construction of the Berkeley Pit and associated facilities also resulted in removal of much of the deposited wastes in areas above the present day Weed Concentrator complex.

The Parrott Smelter (Figures 1-2 and 1-3) was one of the largest facilities that historically impacted areas along the upper reaches of Area I. It was opened in 1881 and terminated operations in 1910, following the Anaconda Company's acquisition of the mill (Smith, 1952). Peak annual copper production at the mill was over 14 million pounds (HRA, 1983). Limited drilling completed during the Phase I RI (MultiTech, 1987) confirmed the presence of buried tailings material in the general vicinity of the historic Parrott Smelter tailings pond.

The lower portion of Area I (from Montana Street to below the Colorado Tailings) is located in an area that has historically hosted milling and smelting activity, associated primarily with four mills: the Butte Reduction Works Mill, the Domestic Manganese and Development Company facility, the Rocky Mountain Phosphates operation, and the Colorado Smelter (Figure 1-2). The Butte Reduction Works were constructed in 1883 and operated nearly continuously until 1911 when a fire destroyed the plant (HRA, 1983). Peak annual copper production of the smelter was over 19 million pounds.

The Domestic Manganese and Development Company facility began operations in 1928 and was closed in about 1959 (HRA, 1983). The plant beneficiated manganese ore. The Rocky Mountain Phosphates operation commenced operation at the same site in 1960. This plant produced tricalcium phosphate animal feed supplement until its closure in 1964 (HRA, 1983).

The Colorado Smelter was constructed in 1878 and operated until about 1904. This smelter reached peak production in 1902 with an annual copper production of over 10 million pounds (HRA, 1983). Tailings resulting from the operation of the facility were deposited on to the Silver Bow Creek floodplain. Through time, the area of tailings disposal encroached on Silver Bow Creek necessitating rechannelization of the stream to the north.

The lower portion of Area I is currently characterized by mining, smelting, and milling waste deposits. It is bordered to the north by light industrial facilities, to the south by Interstate 90/15, and to the east by the city of Butte. Silver Bow Creek exits the valley to the west. The Butte sewage treatment plant is also located in this area as are stockpiles of manganese. Several manganese slag walls are present in the area confining tailings and channelizing Silver Bow Creek as it flows through the area. Missoula Gulch is the largest tributary entering Silver Bow Creek in this area. Missoula Gulch is an intermittent drainage with little discharge, except during spring snowmelt or during precipitation events. The Colorado Tailings are a sizable geomorphic feature in the lower end of Area I. This tailings deposit is generally barren of vegetation and covers an area of approximately 40 acres.

Other features of interest adjacent to the lower reaches of Area I include the Montana Pole and Treating Company facility located south of the Butte Reduction Works area, and Montana Power Company's transformer storage yard. The Montana Pole site contains documented organic contamination associated with historic use of pentachlorophenol (PCP) and diesel at the facility; the site is currently undergoing remediation under the auspices of the EPA and is also scheduled for a RI/FS in the near future. The transformer storage yard may be a source of organic contamination.

1.4 SITE DESCRIPTION

Approximate boundaries of the Area I Operable Unit are depicted in Figure 1-2. The lateral extent of the study area in the vicinity of the Metro Storm Drain incorporates surface areas that drain directly to the Metro Storm Drain. Areas draining to storm sewers that enter the Metro Storm Drain and Missoula Gulch and eventually into Silver Bow Creek were excluded from the Area I study area. These potential sources of contamination were evaluated during this study as point source inputs (storm sewer outfalls) to Area I. Likewise, no efforts were made during this study to directly characterize contaminant sources and pathways in the Weed Concentrator area. Areas not evaluated during the Area I Phase II Remedial Investigation are being studied in conjunction with other studies being completed on Butte Hill by the EPA.

Residential areas within Area I were generally excluded from the study area. Some isolated residences present within the study area boundary (Figure 1-2) were evaluated with respect to environmental impacts on surface water systems; no specific efforts were made to characterize these residences from a human health perspective. Studies directed toward evaluating human health risks associated with residential areas in Butte is being completed in a separate EPA study of the Butte Hill.

The study area for groundwater investigations in Area I was more widespread than that for other environmental media, particularly in the vicinity of the Metro Storm Drain (Figure 1-2). The study area boundary for groundwater investigations was expanded in the vicinity of the Metro Storm Drain in an attempt to determine the spatial extent of inorganic contaminants in groundwater derived from sources located within the general study area. The upper (northeastern) boundary of the groundwater study area along the Metro Storm

Drain was generally coincident with location of a groundwater divide caused by the Berkeley Pit. For purposes of this study, it was assumed that the water level in the Berkeley Pit will be maintained at a sufficient depth such that the presence of the groundwater divide in the upper Metro Storm Drain area is maintained. The bedrock groundwater system in the vicinity of Area I is not included in this study but is being evaluated under EPA's studies of the Butte Hill.

1.5 SITE CHARACTERISTICS

1.5.1 Physiography/Demography

The Area I Operable Unit is located just west of the Continental Divide in southwestern Montana at an elevation of approximately 5400 feet above mean sea level. The site is included in the Northern Rocky Mountain physiographic province. Area I is located on the northern flanks of the Summit Valley which is characterized by gently sloping terrain bound by mountains associated with the Boulder Batholith and Continental Divide to the north and east. The area to the south is typified by the Summit Valley which hosts Blacktail Creek. Blacktail Creek originates in the Highland Mountains located approximately 15 air miles south of Butte. To the west, moderately steep hills are present which intrude on the valley bottom.

The Area I Operable Unit covers an area of approximately 500 acres. The upper (northeastern) portion of the study area is typified by residential and commercial development; the Weed Concentrator associated with Montana Resource, Inc.'s mining operations is present at the upper end of the area. The lower (southwestern) portion of the study area is characterized by light industrial activity and scattered residences. Manganese stockpiles, slag walls, and tailing deposits are also present in the lower end of the study area.

The study area is located within and adjacent to the city of Butte. Butte has historically been a center for mining activities for the region, particularly in conjunction with copper mining. The estimated population for Butte-Silver Bow in 1988 was 33,200 (U.S. Bureau of Census, 1989). In 1980, the city-county had a population of 38,092 (U.S. Bureau of

Census, 1980); population in Butte-Silver Bow peaked in 1920 at a 60,313 persons (Dodge, 1976).

Portions of the city of Butte are directly adjacent to the Area I Operable Unit. Approximately 50 individual households are located within the defined study area boundary used for soils investigations. The Butte-Silver Bow shop complex is present within the operable unit at the upper end of the study area. The Butte Civic Center is also located within the middle portion of the operable unit. Other major demographic features within the study area include a retirement home, a commercial campground, a restaurant, an asphalt recycling center, Butte's sewage treatment plant, and a meat packing plant.

1.5.2 Climate

The Butte area has a continental climate characterized by moderately warm days in summer and cold winters. Average mid-summer temperatures average between 60° and 65° F; average mid-winter temperatures are about 20° F. Temperature extremes rarely exceed 100° F and often are well below zero. Record recorded extreme temperatures in Butte are 100° F on July 21, 1931 and minus 52° F on February 9, 1933 and December 23, 1983.

Annual precipitation in Butte varies from six to 20 inches; the average annual precipitation is 11.72 inches for the period of record from 1951 to 1988 (NOAA, 1988). The greatest amount of precipitation typically occurs during the months of May and June. Precipitation during the winter months typically occurs as snow. Measurable snowcover in the Butte area has occurred during all months of the year. The average growing season in Butte is 81 days (NOAA, 1971). The average first frost occurs on August 28; the average last killing frost occurs on June 8 (NOAA, 1971).

1.5.3 Geology

The geology of the Area I Operable Unit is diverse with rocks ranging from Cretaceous intrusives to Quaternary alluvium. Rocks in the Butte area are largely siliceous with zones containing ore-grade sulfide minerals and other associated sulfide deposits. The Boulder Batholith bounds Area I to the north; this feature is composed primarily of highly mineralized quartz monzonite.

Tertiary-aged unconsolidated valley fill and alluvial deposits associated with Silver Bow Creek are present throughout Area I ranging in thickness from over 300 feet near the upper end of Area I to less than 30 feet in the vicinity of the Colorado Tailings. These deposits consist of poorly sorted gravel, sand, silt, and clay which are not easily correlatable laterally (MultiTech, 1987). Isolated cobbles and boulders are also present within these sediments.

The Butte Mining District has been a major producer of gold, silver, and copper, with lesser quantities of cadmium, bismuth, arsenic, selenium, and tellurium (Miller, 1973). Tailings, waste rock, leach pond deposits, and smelter wastes are present at numerous sites in the Butte area. These deposits generally overlie alluvium, colluvium, or fractured bedrock and are occasionally covered over by man-emplaced fill material.

1.5.4 Soils

A diversity of soil types is present in the Area I Operable Unit study area. Soils within the study area were developed primarily on upland slopes under conifer forests or on valley-fill sediments under grassland vegetation. Adjacent to Silver Bow Creek, thin gravel-textured to deep, fine-grained alluvial soils have developed. Nutrient rich, organic soils (peat) of various thicknesses are present in some low or wetland areas.

Surfaces on which natural soils developed have been altered by man through much of Area I. The original land surface along the historic course of Silver Bow Creek has been buried by mining waste or other man-emplaced fill materials or have been disturbed through urban development activities. Man-emplaced deposits vary substantially in metal levels.

Mining-related wastes in the study area are generally sandy textured because of milling activities, and typically contain high concentrations of metals and sulfide minerals. Generally, oxidation of sulfide minerals produces acidic conditions that increase the solubility of heavy metals. These processes limit vegetation establishment which further limits soil development.

1.5.5 Surface Hydrology

The surface water system in the Area I Operable Unit consists of three primary components: the Metro Storm Drain, Blacktail Creek, and Silver Bow Creek (Figure 1-1). The Metro Storm Drain generally follows the historic Silver Bow Creek channel from below the Weed Concentrator to its confluence with Blacktail Creek. The Metro Storm Drain was constructed during the 1930s under a Works Progress Administration (WPA) program to provide a means of transporting water and mine wastes out of Butte in response to stream aggradation occurring during the early part of the century. The project consisted of realignment and filling of the original Silver Bow Creek drainage, which previously was a lowland swampy area with numerous mine waste ponds along its upper reach.

The upper reaches of Silver Bow Creek were truncated because of construction of the Berkeley Pit, which was initiated in 1955. Because of this, the entire flow of Silver Bow Creek was intercepted by the pit, a situation which is occurring today.

The upper Metro Storm Drain is typically dry, except during snowmelt or precipitation events. These conditions are monitored by a continuously recording weir operated by the U.S. Geological Survey below Continental Drive. The Clearwater Ditch (Figure 1-2) is routed into the Metro Storm Drain at its head. This ditch routes water from the western flanks of Rampart Mountain around the Berkeley Pit and into the Metro Storm Drain. The Clearwater Ditch is also typically dry except during snowmelt runoff events or during prolonged precipitation events. A channel also enters the head of the Metro Storm Drain from the Weed Concentrator complex. This channel has historically been used as a permitted discharge from the Barrel Ponds associated with the Weed Concentrator (Figure 1-2); there has been no evidence of discharge from the Barrel Ponds into the Metro Storm Drain since 1986 although water is currently contained in the ponds.

Several storm outfalls are directed into the Metro Storm Drain from below the Weed Concentrator to its confluence with Blacktail Creek. These outfalls drain various areas within Butte ranging from parking lot drains to major storm drain systems exiting waters from large areas on Butte Hill.

The Metro Storm Drain becomes a perennial surface water course near the middle reaches of the system. This is because the base of the Metro Storm Drain intercepts the shallow groundwater system in the area and serves as a linear drain. The quantity of flow measured in the Metro Storm Drain near its mouth during the Phase I Remedial Investigation (MultiTech, 1987) during non-runoff conditions was typically 0.4 to 0.5 cubic feet per second (cfs).

Blacktail Creek originates about 15 miles south of its confluence with the Metro Storm Drain in the Highland Mountains and drains approximately 75 square miles. Blacktail Creek is a perennial stream which supplies the majority of flow in modern day Silver Bow Creek. The USGS installed a continuously recording gaging station at the mouth of Blacktail Creek in October, 1988; this monitoring program is ongoing. Average flow in Blacktail Creek at its mouth since the gaging station was installed is 11.2 cubic feet per second (cfs).

For this report, the headwaters of Silver Bow Creek is defined as the confluence of the Metro Storm Drain and Blacktail Creek. Silver Bow Creek from its head to below the Colorado Tailings flows through an area which has been altered by man's activities. These alterations have resulted in a present day surface water course which has been rerouted from the historical location of the channel. Silver Bow Creek is confined within a series of manganese slag walls in the vicinity of the historic Butte Reduction Works area and has been redirected north of the Colorado Tailings through an excavated channel armored with riprap.

Within the lower part of Area I, storm outfalls enter Silver Bow Creek from the north near Montana Street and overland runoff moves directly into Silver Bow Creek from areas along the floodplain, including the Butte Reduction Works area and the Colorado Tailings. In addition, the Butte Metro Sewage Treatment Plant discharges treated effluent to Silver Bow Creek near the Colorado Tailings and Missoula Gulch enters the stream from the north just east of the Colorado Tailings.

The Butte Metro Sewage Treatment Plant discharge averages approximately 7.4 cfs and increases the average flow in Silver Bow Creek by about 30% (MultiTech, 1987). Missoula

Gulch is an intermittent stream which drains most of the west side of Butte. This drainage contributes little flow to Silver Bow Creek except during runoff conditions in Butte.

The USGS has operated a continuously recording gaging station on Silver Bow Creek just below the Colorado Tailings since 1984. Average flow measured at this station from 1983-1988 is 23.8 cfs; highest recorded flow was 424 cfs on May 25, 1987 and lowest recorded flow was 9.7 cfs on September 1 and September 5, 1988.

1.5.6 Groundwater Hydrology

Groundwater resources in the vicinity of Area I generally are associated with two water-bearing units. These include unconsolidated sediments associated with Tertiary and Quaternary aged valley fill overlying weathered and fractured bedrock units typically comprised of Tertiary aged quartz monzonite associated with the Boulder Batholith. The occurrence of groundwater in the unconsolidated valley fill is generally associated with laterally discontinuous coarse grained sand and gravel units. Depth to water in the unconsolidated valley fill ranges from two to over 30 feet. Well yields in the valley fill material typically range from less than five gallons per minute (gpm) to over 30 gpm.

Groundwater flow paths in the upper end of Area I near the Weed Concentrator are influenced by the presence of the Berkeley Pit. A groundwater divide is present in the unconsolidated material adjacent to the Metro Storm Drain. Groundwater north of this divide moves to the Berkeley Pit; groundwater movement south of the divide parallels the Metro Storm Drain.

Groundwater discharges to the lower reaches of the Metro Storm Drain from about Harrison Avenue to Blacktail Creek resulting in perennial flow in the lower half of the Metro Storm Drain. Vertical groundwater movement in the upper end of Area I is likely influenced by past dewatering activities associated with the Berkeley Pit. Water level data obtained at a well cluster near the upper end of the Metro Storm Drain indicates a downward gradient of approximately 3% to depths of approximately 150 feet (MultiTech, 1987). The measured downward component to groundwater movement in this area may indicate discharge of the shallow groundwater system into a deeper, more permeable unit, possibly associated with the upper portion of the bedrock groundwater system.

Temporal trends in groundwater levels indicate a measurable water level decline in monitoring wells constructed in the vicinity of the Weed Concentrator. The decline of water levels appears to correlate with termination of operations at the Weed Concentrator when on-site process ponds were drained. The dropping water levels in this area may indicate the decline of a groundwater mound that was created by leakage from these ponds during active operations at the concentrator.

Groundwater movement in the lower reaches of Area I is generally parallel to but slightly toward Silver Bow Creek, indicative of gaining stream conditions. Discharge of groundwater into Silver Bow Creek was confirmed by synoptic flow measurements of Silver Bow Creek during the Phase I Remedial Investigation (MultiTech, 1987). Limited aquifer testing of groundwater-bearing zones 100 to 150 feet below ground surface completed during the Phase I Remedial Investigation (MultiTech, 1987) indicate low hydraulic conductivities, on the order of 10 to 30 gallons/day/square foot.

There has been minimal development of the water-yielding zones in the unconsolidated material in the Butte area as a water resource. This is primarily because most households and commercial businesses are supplied by a city-wide water distribution system, owned and operated by the Butte Water Company. Water for this system is derived from surface water sources located both within and outside of the Summit Valley. Recently, several households in Butte and the Butte/Silver Bow Government have begun installing irrigation wells which derive water from the unconsolidated material aquifer.

The quality of groundwater in the unconsolidated valley fill aquifers in Butte appears to be impacted by several sources of man-made contamination primarily associated with tailings deposits. Groundwater outside of the source areas is generally a calcium bicarbonate water; groundwater proximal to the source areas is a calcium sulfate type water (MultiTech, 1987). Concentrations of dissolved metals, including iron, zinc, copper, and cadmium in and near the source areas are up to four orders of magnitude higher than concentrations measured in groundwater located upgradient and cross gradient of identified source areas (MultiTech, 1987).

The occurrence of groundwater in the bedrock system both adjacent and subjacent to Area I is less clearly understood than the unconsolidated valley fill aquifers. Much of the bedrock groundwater system has been impacted by dewatering activities associated with historic mining activities at the Travona mine shaft, located near the west end of Butte, and at the Kelley mine shaft, located near the Berkeley Pit. Water pumped from these shafts lowered water levels in the bedrock system; the impact of dewatering activities at the Kelley shaft on the bedrock groundwater system is still realized today.

Groundwater in the bedrock system occurs in fractures and in weathered zones near the top of the rock package. Hydraulic characteristics of the bedrock system are poorly understood; it is probable that the system is complex because of the secondary permeability nature of materials hosting groundwater and because of the large network of underground mine shafts and tunnels located in bedrock underlying Butte.

There has been minimal development of bedrock groundwater resources in the Butte area owing both to impacts of shaft dewatering and because the area is serviced by the Butte Water Company. Pumping rates from Kelley shaft, when the pumping system was operational, were reported to be on the order of 5000 gpm (Hydrometrics, 1982). This provides some indication of the magnitude of groundwater movement through the bedrock system although a component of this discharge was probably derived from adjacent alluvial material.

The quality of groundwater in the bedrock system is variable and may be related to mineralogical zoning. Samples collected from several mine shafts located near the Berkeley Pit contain dissolved metals in concentrations which exceed primary and secondary drinking water standards (MBMG, 1988). Groundwater quality in the west camp of Butte (near the Travona Shaft) appears to be of much better quality; arsenic is the only parameter which exceeds primary drinking water standards (MBMG, 1988).

1.5.7 Land Use

Land use in the Area I Operable Unit is zoned by the Butte-Silver Bow government. The primary zoning classifications for Area I include residential and mining.

Several residences are located in Area I, particularly along the Metro Storm Drain. The City-County shop complex is located near the upper end of Area I. This facility covers a relatively large area and houses city equipment and offices. A large portion of the area along the Metro Storm Drain is currently unused probably because the area exhibits shallow groundwater and bogs.

The portion of Area I between Montana Street and the Colorado Tailings is typified by mine wastes, stockpiles of manganese, and light industry. Public access to the manganese stockpile area and the Butte sewage treatment plant is limited by chain-link fences and locked gates.

Access to the Colorado Tailings is primarily by foot; no easily accessible roads are routed to the exposed tailings. The area below the Colorado Tailings is used primarily for agricultural purposes; a corral is located in this area which temporarily confines livestock for slaughter at the Ranchland Packing Company.

Observations of dirt bike traffic and pedestrian traffic throughout Area I were made routinely during both the Phase I RI (MultiTech, 1987) and during the Phase II RI. On several occasions, children were observed playing and swimming in the Metro Storm Drain and in Silver Bow Creek. Because of the proximity of the operable unit to residential areas, Area I is used frequently by recreationists and workers alike.

1.6 PROJECT OBJECTIVES

Objectives to completing the Phase II RI at the Area I Operable Unit are described in the project sampling and analysis plan (CH2M HILL, 1989d). In general, objectives of the investigation were to obtain data necessary to evaluate the following:

- Areas that may be sources of windblown dust.

- The approximate areal and vertical extent of soil contamination.

- The approximate extent of groundwater contamination and the pathways of contaminant movement in the area's shallow groundwater systems.

- The impact of high flow on contaminant transport in the surface water system.

- The occurrence of organic compounds in the surface water system.

Other objectives to the investigation were to collect data to provide a basis for further characterization of the impact of exposed tailings/contaminated soils located within the operable unit on public health and the environment. Acquisition of soils data were deemed necessary to support a public health and environmental assessment of the operable unit and to evaluate various remedial alternatives for the area during the site feasibility study.

Based upon data gaps identified in CH2M HILL (1989c), four separate studies were completed to meet the stated project objectives. These included efforts to characterize surface water, groundwater, dispersed tailings, and impounded tailings.

Specific objectives for the various investigations completed during the Phase II RI included:

- Surface Water Investigation -- Objectives for completing a surface water investigation were to provide data to characterize the quality and parameter-specific loads in the study area's surface water during high flow conditions and to determine if organic contaminants are present in surface water during various flow regimes.

- Groundwater Investigation -- Objectives for completing a groundwater investigation in Area I were to: (1) collect sufficient data to determine the nature and extent of groundwater contamination within the study area vertically, areally, and seasonally; (2) better define pathways and hydraulics of contaminant movement in the area's groundwater system; and, (3) provide data to evaluate risks to public health.

- Dispersed Tailings/Contaminated Soils Sampling -- objectives for this work task were to: (1) characterize the nature and extent of dispersed contamination within the study area boundaries; (2) provide data to support a public health and environmental assessment for the operable unit; and, (3) provide data to determine the impact of this contaminant source on receiving surface water and groundwater systems.

- Impounded Sources investigations -- Objectives for completing this work task were to: (1) determine the approximate volume of contaminated material associated with these deposits; (2) determine the nature of contamination associated with impounded deposits; and, (3) provide data to assess the impact of these deposits on groundwater and surface water resources and on air quality.

Determinations of the "nature and extent" of contamination in relation to groundwater, dispersed tailings/contaminated soils, and impounded tailings investigations were a somewhat subjective study objective. Precise definition of the nature and extent of contamination in Area I was not completed during this RI because of site complexities and because the size of the operable unit did not lend itself to this type of analysis at this juncture in the RI/FS process. A reasonable understanding of the nature, extent, and approximate volumes of contamination in soils and groundwater was acquired to support additional studies of the site. The study fell short of identifying specific locations exhibiting anomalous contaminant concentrations. This type of detailed site analysis (if necessary) will be completed at a later time.

2.0 SURFACE WATER INVESTIGATION

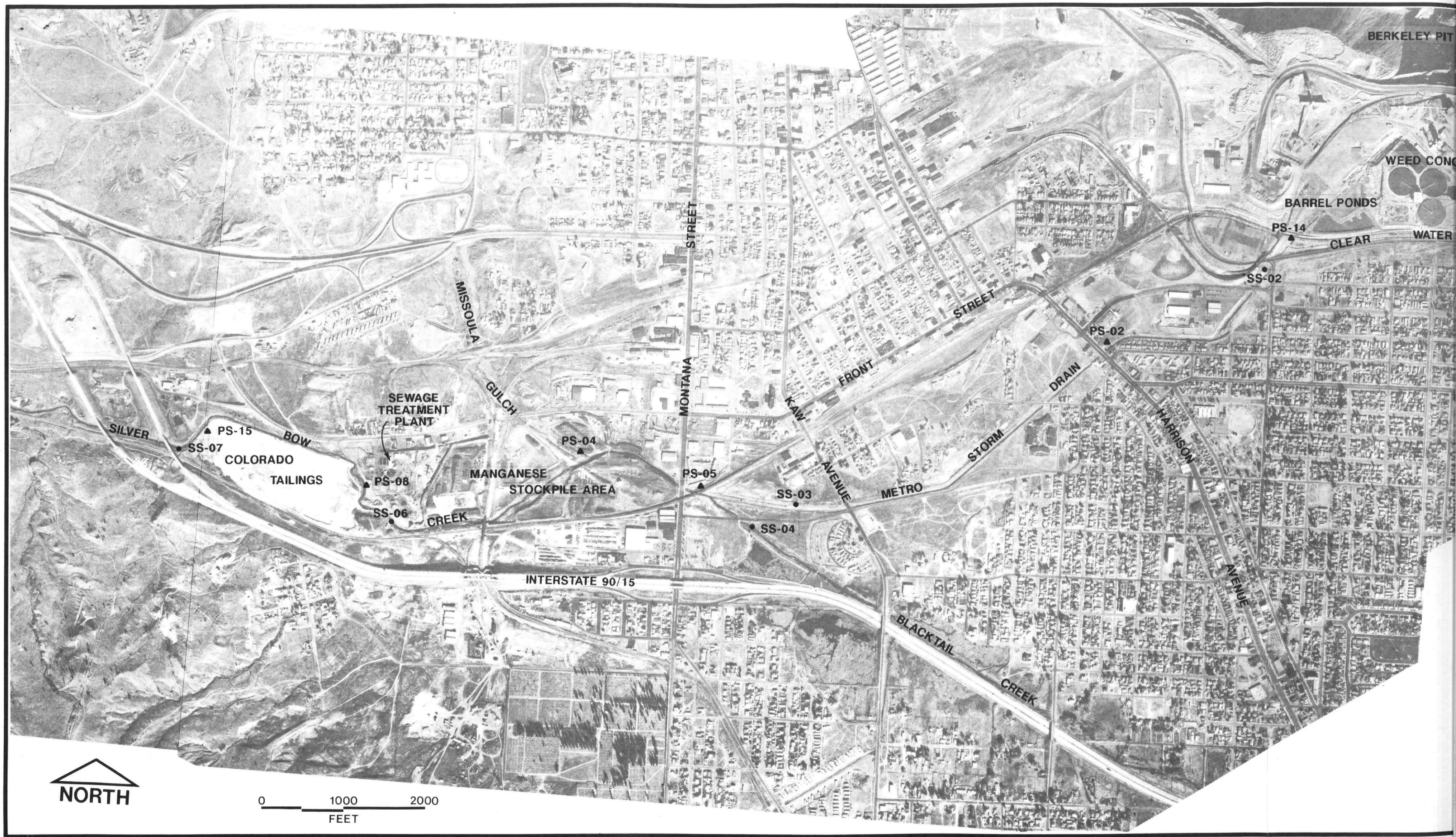
2.1 METHODS

This section provides a brief description of methods used to collect surface water samples during two sampling events completed during the Area I Operable Unit Phase II Remedial Investigation. Surface water sampling performed during the Phase II Remedial Investigation included sampling during a snowmelt event and during baseflow conditions in the area.

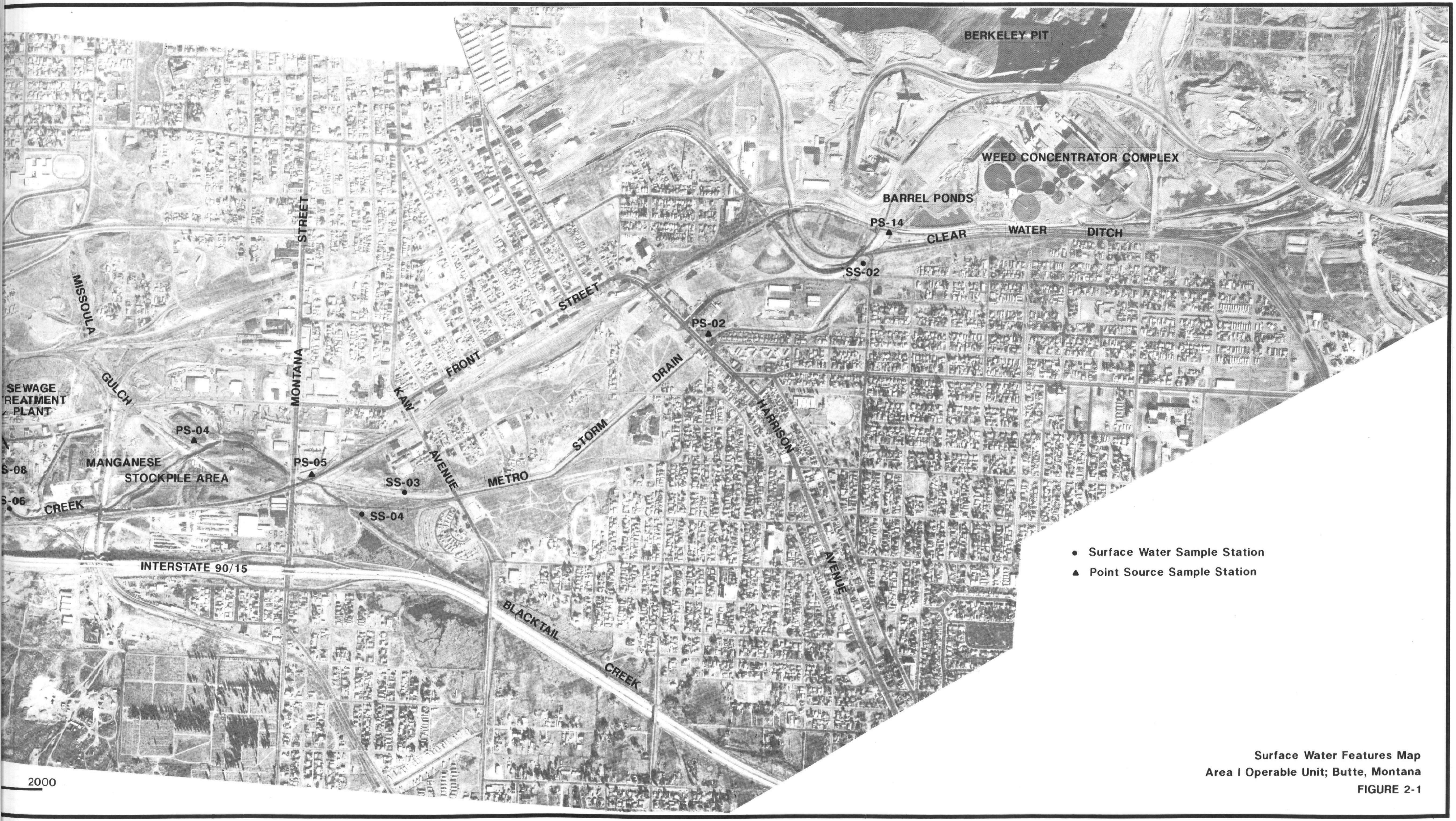
Figure 2-1 shows locations of surface water sampling stations utilized during the March 10, 1989 snowmelt sampling event in the Area I Operable Unit. Table 2-1 presents descriptions of sample site locations. Detailed descriptions of sampling sites are contained in Appendix A-1. The design of this sampling network allowed for characterization of the quality and flow characteristics of the surface water system entering, within, and exiting Area I. Only major storm outfalls to the Metro Storm Drain and Silver Bow Creek were sampled during the March 10, 1989 sampling episode; several other minor storm outfalls enter the primary water courses in the area.

The objective of field activities associated with the snowmelt sampling episode was to initiate sampling activities at each station during the rising limb of the snowmelt hydrograph and continue sampling though the peak and into the descending limb of the hydrograph. This situation occurred at several stations sampled; the hydrograph for stations above which there was a large drainage area did not exhibit a peak to the hydrograph during the time period in which these stations were sampled. Further discussion of this phenomenon is presented in Section 2.3.

During the snowmelt sampling event, field crews collected water samples every hour at each sample site. Field parameters, including pH, specific conductivity, and temperature were measured immediately following collection of each sample. Stream discharge was also measured every hour, coincident with sampling. Discharge was measured by using a current meter or by relating creek stage to rating curves established for those sites equipped with continuously recording gages.



BERKELEY PIT
WEED CONC
BARREL PONDS
PS-14
CLEAR
WATER
SS-02
FRONT
STREET
PS-02
STORM
DRAIN
METRO
HARRISON
AVENUE
KAW
AVENUE
MONTANA
STREET
MISSOULA
GULCH
SEWAGE
TREATMENT
PLANT
SILVER
BOW
CREEK
PS-15
SS-07
COLORADO
TAILINGS
PS-08
SS-06
MANGANESE
STOCKPILE AREA
PS-04
PS-05
SS-03
SS-04
INTERSTATE 90/15
BLACKTAIL
CREEK
NORTH
0
1000
2000
FEET



Surface Water Features Map
Area I Operable Unit; Butte, Montana
FIGURE 2-1

TABLE 2-1

SURFACE WATER SAMPLE STATION LOCATIONS USED DURING MARCH 10, 1989 SNOWMELT RUNOFF SAMPLING

STATION NO.[1]	DESCRIPTION
SS-02	Metro Storm drain at head at USGS gaging station.
SS-03	Metro Storm drain near mouth; 200 feet west of Kaw Avenue.
SS-04	Blacktail Creek near mouth at USGS gaging station.
SS-06	Silver Bow Creek above Colorado Tailings.
SS-07	Silver Bow Creek below Colorado Tailings at USGS gaging station.
PS-02	Harrison Avenue storm sewer outfall near Civic Center.
PS-04	Missoula Gulch at mouth.
PS-05	Kaw Avenue storm sewer outfall near Montana Street.
PS-08	Butte Sewage Treatment Plant discharge.
PS-14	Drainage entering Metro Storm Drain from Weed Concentrator area - above Clearwater Ditch.
PS-15	Drainage on west end of Colorado Tailings to Silver Bow Creek.

[1] Station Locations shown on Figure 2-1.

Water quality samples were collected using a DH-48 sampler where adequate stream depth and discharge warranted use of this type of sampling device. At these stations, equal discharge sampling techniques were used. This method involved depth integrated sampling at four to six points in the stream cross section representing sections of equal stream discharge. Grab samples were collected at stations which were not conducive to depth and discharge integrated sampling techniques.

Collected samples were placed in ice-filled coolers for transport. Hourly samples collected from each station were then composited into a single sample. This procedure was completed by first calculating the volume of the entire runoff hydrograph for each sample site. The proportionate volume of the hydrograph that each hourly sample represented was then calculated. Each hourly sample was then partitioned utilizing a cone splitter to obtain a proportionate volume of sample which was representative of its relative percentage of the snowmelt hydrograph. These subsamples were then combined into a single sample set.

Following sample compositing, samples were filtered and preserved, as necessary, and prepared for shipment to an analytical laboratory. Samples were analyzed for common ions, selected nutrients, total suspended solids, and total, dissolved, and acid soluble metals. Table 2-2 summarizes the parameter list for surface water sampling completed during the Phase II Remedial Investigation. Sample preparation for acid soluble metal parameters was completed prior to sample shipment in accordance with the project sampling and analysis plan (CH2M HILL, 1989d).

One additional sample was collected at each station during the snowmelt sampling event for analysis of hexavalent chromium. This sample was collected at or near the peak of the hydrograph at each station. Because of the short holding time for analysis of this parameter (24 hours), these samples were shipped to an analytical laboratory immediately following sample collection via express mail. Therefore, hexavalent chromium analyses do not represent a composite of samples collected during the sampling event but rather provide a measure of concentrations at or near the peak of the snowmelt hydrograph.

Samples for analysis of contract laboratory program routine analytical services organic compounds were collected during or near peaks in the hydrographs at stations SS-03, SS-04, and SS-07 (Figure 2-1). Two samples were collected at each of these sites in accordance

TABLE 2-2

ANALYTICAL PARAMETER LIST FOR SURFACE WATER SAMPLING COMPLETED DURING THE AREA I PHASE II REMEDIAL INVESTIGATION

Metals*

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Potassium
Selenium
Silver
Sodium
Thallium
Vanadium
Zinc

Common Ions/Nutrients

Alkalinity
Chloride
Fluoride
Nitrite + Nitrate as N
Sulfate
TSS

CLP RAS Organics

Measured Field Parameters

pH
Specific Conductance
Temperature
Discharge

* RAS metals analyzed for total, acid soluble and dissolved constituents.

with methodologies described in the project sampling and analysis plan (CH2M HILL, 1989d). One sample at each station was collected from several points in cross section at the surface of the water and the other was a depth- and discharge-integrated sample collected from below the water surface. This sampling methodology provided a means to measure those compounds which may be floating on the water surface and those which may be travelling within the water profile as "sinkers."

Surface water samples were also collected during baseflow conditions for contract laboratory program routine analytical services organic analysis on August 21, 1989 (Table 2-2). Sampled sites were the same stations used for organic sampling during snowmelt runoff (SS-03, SS-04, and SS-07, Figure 2-1). Methods used to measure discharge and collect samples during this sampling event were identical to those described for runoff sampling with one exception. Grab samples were collected at station SS-03 in the Metro Storm Drain because the depth of water in the storm drain at the time of this sampling event was not sufficient for depth- and discharge-integrated sampling techniques.

Quality control samples were incorporated into the sample train during both sampling events in accordance with the project sampling and analysis plan (CH2M HILL, 1989d). These included duplicate samples (composites), cross-contamination blanks, bottle blanks, and blind field standards. Blind field standards were not available for hexavalent chromium and, hence, were not included with the sample shipment.

2.2 CHANGES TO THE PROJECT SAMPLING AND ANALYSIS PLAN

Two previously undesignated sampling stations identified in the project sampling and analysis plan (CH2M HILL, 1989d) were assigned station numbers during the snowmelt sampling event. These included station PS-14 (Figure 2-1) which represented the sample station located at the mouth of the drainage exiting the Weed Concentrator complex and PS-15 (Figure 2-1) which represented the station located at the west end of the Colorado Tailings. Station PS-15 monitored runoff from the Colorado Tailings which was concentrated in a rill prior to entry into Silver Bow Creek.

Two surface water runoff sampling events were scheduled in the project sampling and analysis plan (CH2M HILL, 1989d). The purpose of the second sampling event was to collect runoff samples during a thunderstorm or frontal type rainfall event. Several attempts were made to sample storm runoff in Butte during spring and summer, 1989. The lack of sufficient precipitation over Area I during the time sampling crews were present resulted in a failed effort to complete this portion of the investigation. If, during the site feasibility study, it is decided this type of data is necessary, a separate effort will be completed to sample this type of runoff event.

2.3 PRESENTATION OF DATA/RESULTS

Discharge and inorganic water quality data resulting from the March 10, 1989 snowmelt runoff sampling event are presented in Appendix A-2. Organic compound water quality data from the March 10 and August 21, 1989 sampling events are contained in Appendix A-3.

2.3.1 Snowmelt Runoff Sampling Event

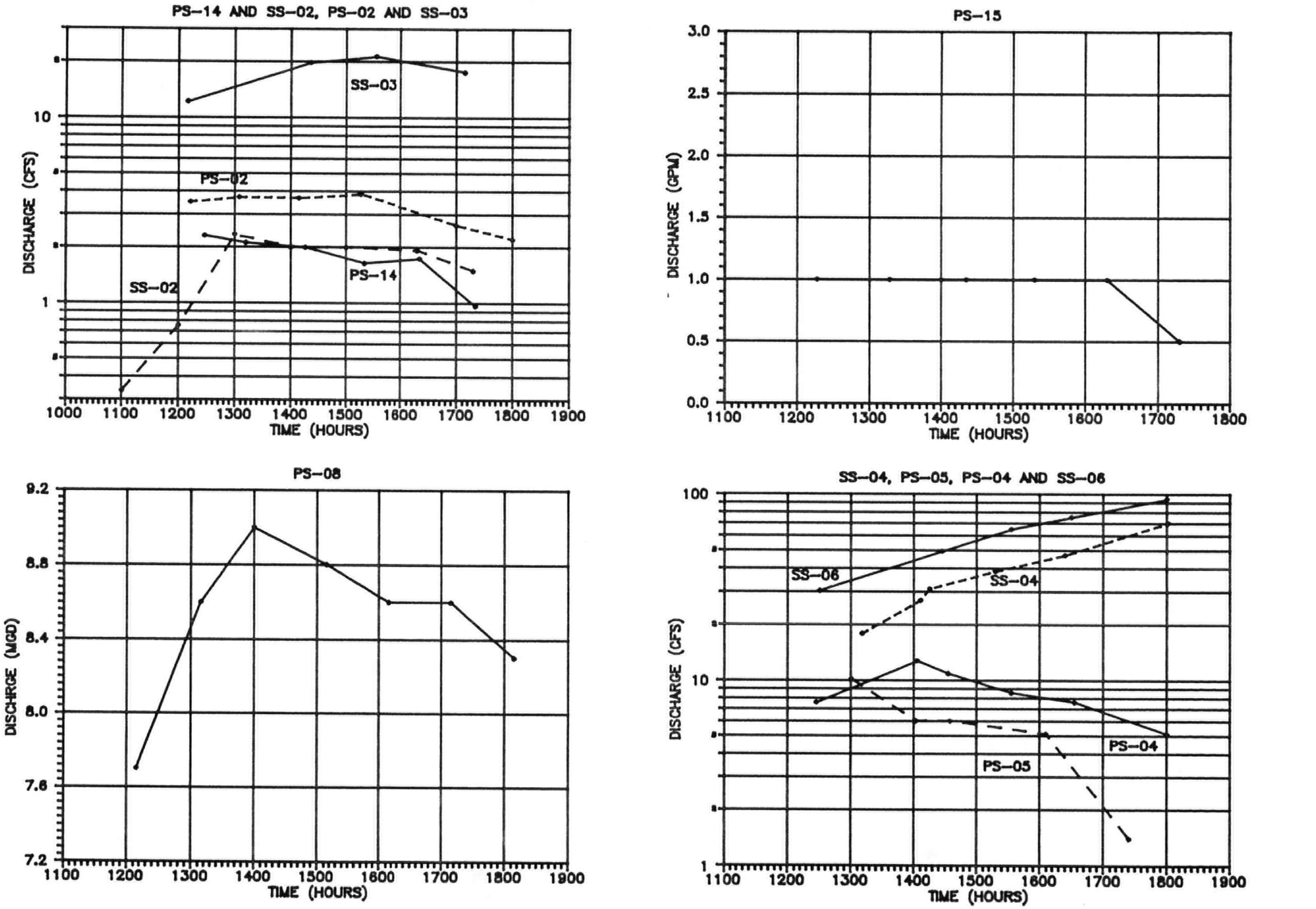
2.3.1.1 Discharge

Figure 2-2 illustrates hydrographs for the various sampling stations monitored during the March 10, 1989 snowmelt runoff sampling event. Discharge at most sites peaked by mid-afternoon and receded into the evening hours. Snowmelt hydrographs for stations SS-04 and SS-06 indicate that a peak in discharge did not occur during the time period during which sampling was completed. These stations are both mainstem sampling sites along Blacktail Creek and Silver Bow Creek, respectively.

Discharge data were not directly collected at station SS-07 (Figure 2-1) during the snowmelt sampling event. Instead, observations of creek stage were made at the adjacent USGS gaging station; these stage data were related to a rating curve established for the site by the USGS. In reviewing data from sites on Blacktail Creek and Silver Bow Creek during the snowmelt runoff event, a sizable discrepancy resulted in comparing flow data derived through use of the USGS rating curve at SS-07 to measured flows at stations located above SS-07, even after adding input flows between the stations. Because of this, loading data presented in subsequent sections for station SS-07 are based on the added flows of station SS-06 on Silver Bow Creek, the Sewage Treatment Plant effluent (PS-08), and the gaged flow off of the Colorado Tailings (PS-15) (Figure 2-1). Although it is recognized this

Hydrographs for Surface Water Stations

Monitored During March 10, 1989 Snowmelt Runoff Sampling Event



Area I Operable Unit Phase II Remedial Investigation

FIGURE 2-2

method of calculating flow for SS-07 is not precise, relative relationships in metals loads can be evaluated.

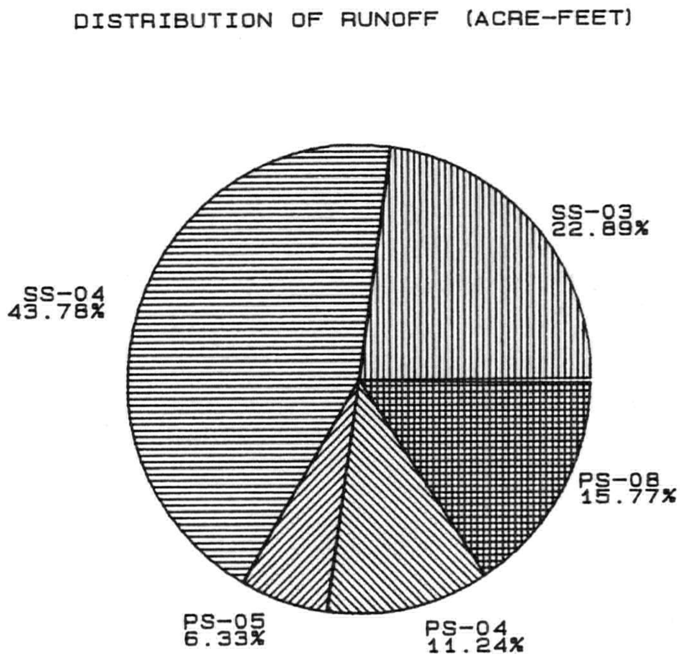
The hydrographs at sites SS-04 and SS-06 did not peak and recede like the other sites monitored during the snowmelt runoff event because of the large drainage area present above these gaging sites. Large drainage areas require a relatively longer period of time for snowmelt runoff occurring in the upper portions of the basin to enter lower reaches of the basin.

Figure 2-3 depicts the relative distribution of runoff volume between sampling stations during the snowmelt event for a common time period. Sampling stations illustrated on Figure 2-3 include those gaged inputs which directly enter Silver Bow Creek in the operable unit. Examination of Figure 2-3 indicates that approximately 43% of the gaged runoff volume was derived from Blacktail Creek (station SS-04). The next largest input was derived from the Metro Storm Drain (23% at station SS-03). Other monitored inputs from the Sewage Treatment Plant effluent (PS-08), Missoula Gulch (PS-04), and the Kaw Avenue storm drain (PS-05) made up the majority of the balance of runoff volume. The total volume of runoff gaged at mainstem sampling site SS-06 was within one percent of the sum of runoff volumes measured at these upstream sampling stations.

2.3.1.2 Water Quality

Figure 2-4 is a trilinear diagram of surface water sampling sites monitored during the March 10, 1989 snowmelt runoff sampling event. Figure 2-5 is a map showing a spatial distribution of stiff diagrams of common ions at sampled sites. Examination of Figure 2-4 indicates sampling stations PS-14, PS-15 and SS-02 group separately from other monitored sites as does station PS-08. Sampling stations PS-14 and SS-02 are located at the upper end of the Metro Storm Drain; station PS-15 monitored runoff from the Colorado Tailings (Figure 2-1). These stations exhibited a calcium sulfate type water with relatively large ion strength (Figure 2-5). Station PS-08 is the sewage treatment plant effluent; this water was a sodium bicarbonate type (Figure 2-5).

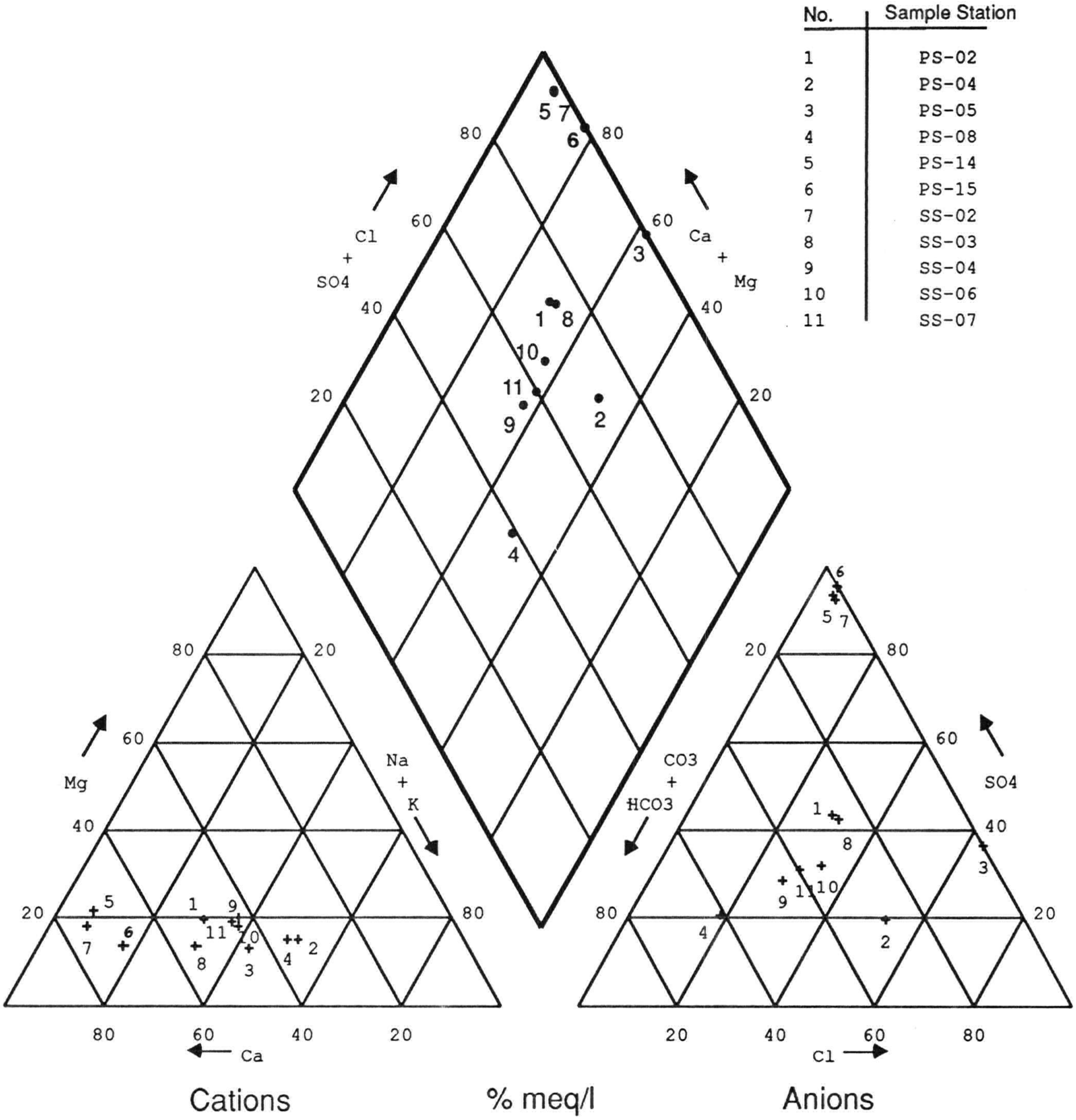
Runoff water from stations PS-02 (Harrison Avenue storm outfall), and SS-03 (Metro Storm Drain at its mouth) also exhibited a calcium sulfate type water. Runoff from Missoula



Sampling Station	Discharge (acre-feet)*
SS-04	74.82
PS-05	10.81
PS-04	19.21
PS-08	26.94
SS-03	39.12
PS-15	0.004

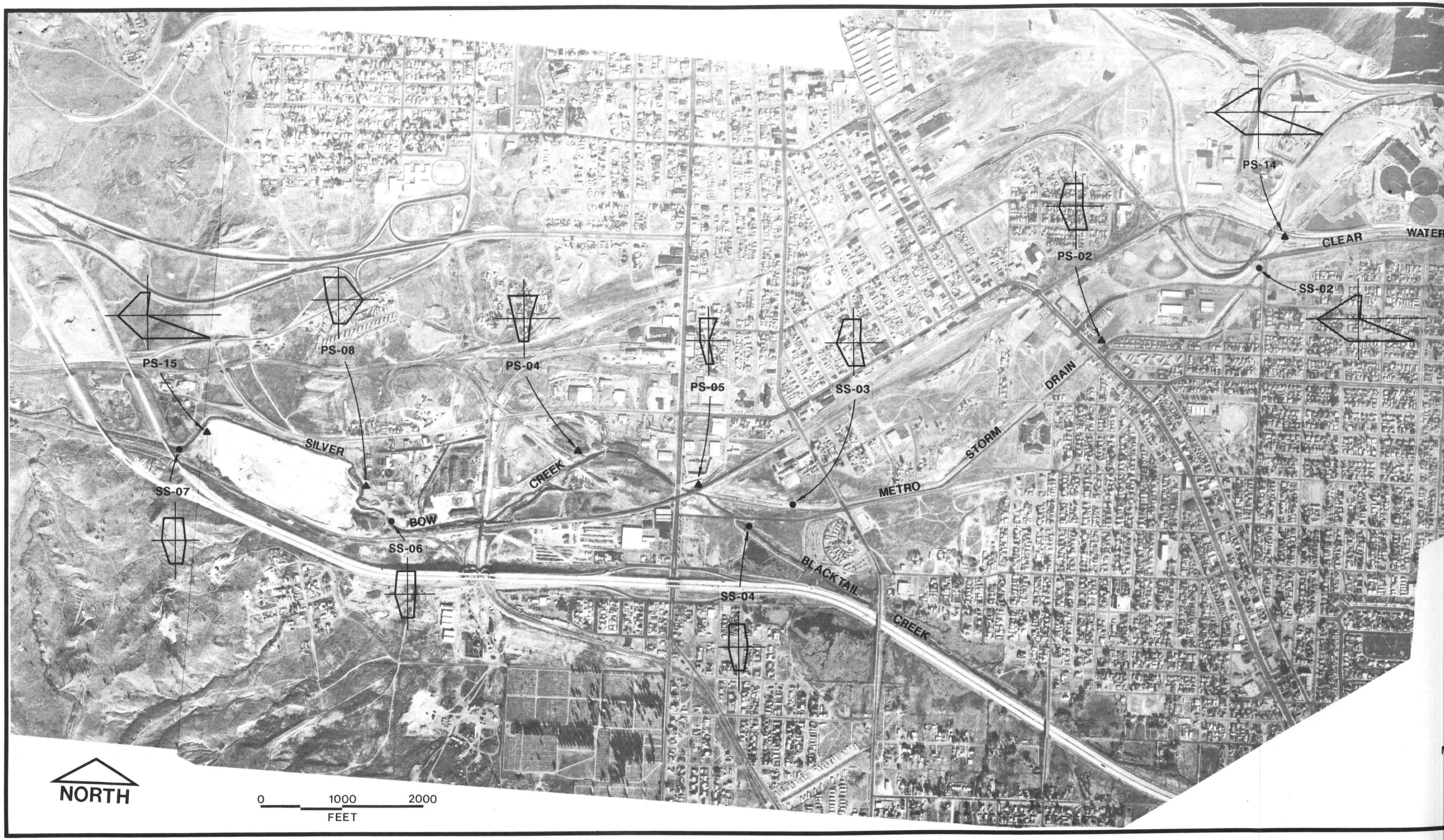
* From 1:30 p.m. to 5:00 p.m.

Distribution of Runoff Volume
During March 10, 1989 Snowmelt Runoff Sampling Event
Area I Operable Unit Phase II Remedial Investigation
FIGURE 2-3

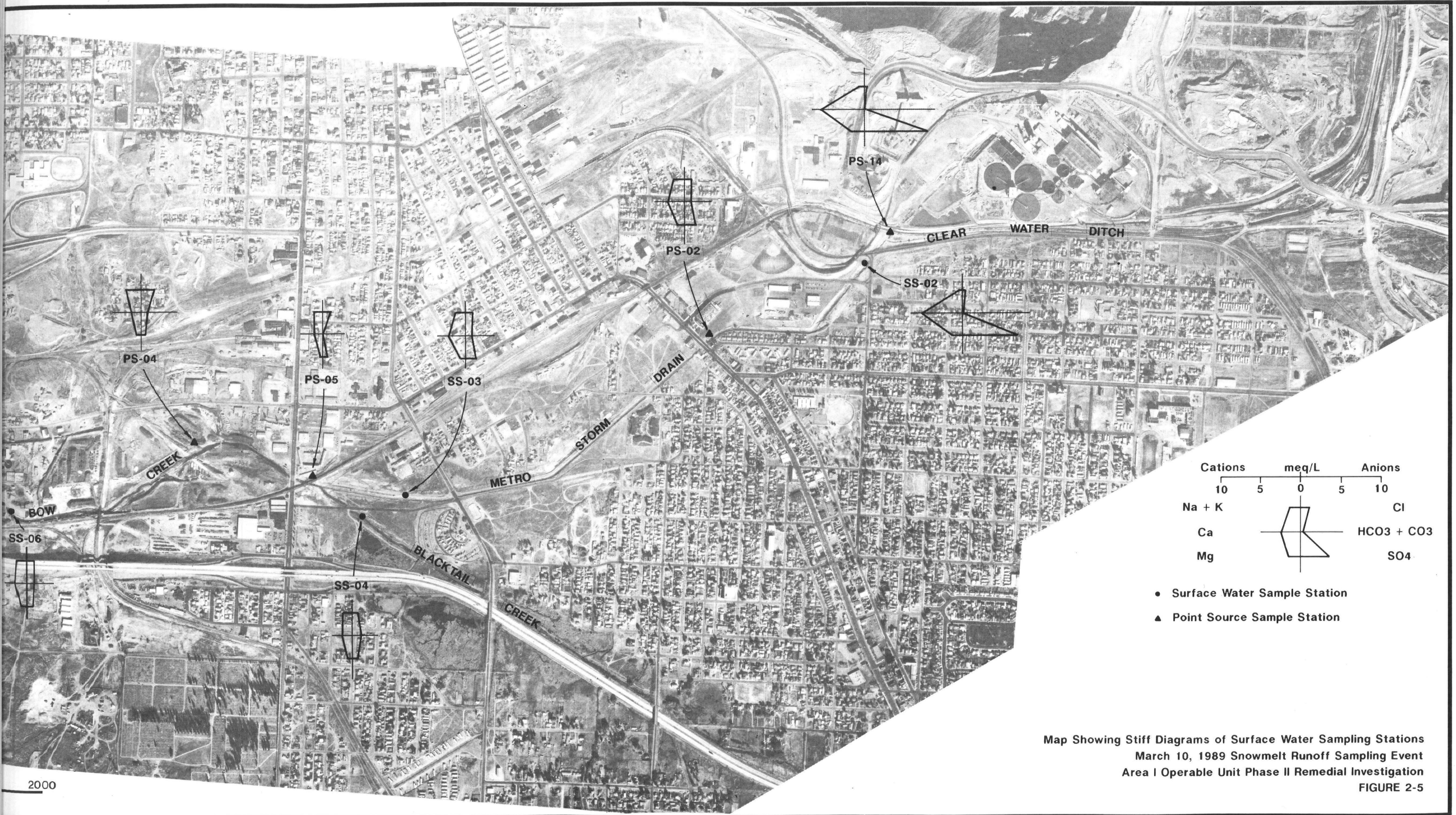


No.	Sample Station
1	PS-02
2	PS-04
3	PS-05
4	PS-08
5	PS-14
6	PS-15
7	SS-02
8	SS-03
9	SS-04
10	SS-06
11	SS-07

Trilinear Diagram of Area I Surface Water
March 10, 1989 Snowmelt Runoff Sampling Event
FIGURE 2-4



PS-14
CLEAR
WATER
PS-02
SS-02
PS-15
PS-08
PS-04
PS-05
SS-03
DRAIN
STORM
METRO
SILVER
CREEK
BOW
SS-07
SS-06
SS-04
BLACKTAIL
CREEK
NORTH
0
1000
2000
FEET



Map Showing Stiff Diagrams of Surface Water Sampling Stations
March 10, 1989 Snowmelt Runoff Sampling Event
Area I Operable Unit Phase II Remedial Investigation
FIGURE 2-5

Gulch (PS-04) and from the Kaw Avenue storm outfall (PS-05) exhibited a sodium chloride type water which was somewhat unique with respect the type of water sampled at other sites during the runoff event. The preponderance of sodium chloride in water draining to these sampling sites may reflect transport of road sand-salt from the streets in Butte or a road sand stockpile area. No efforts were made to identify sources of this material in Butte.

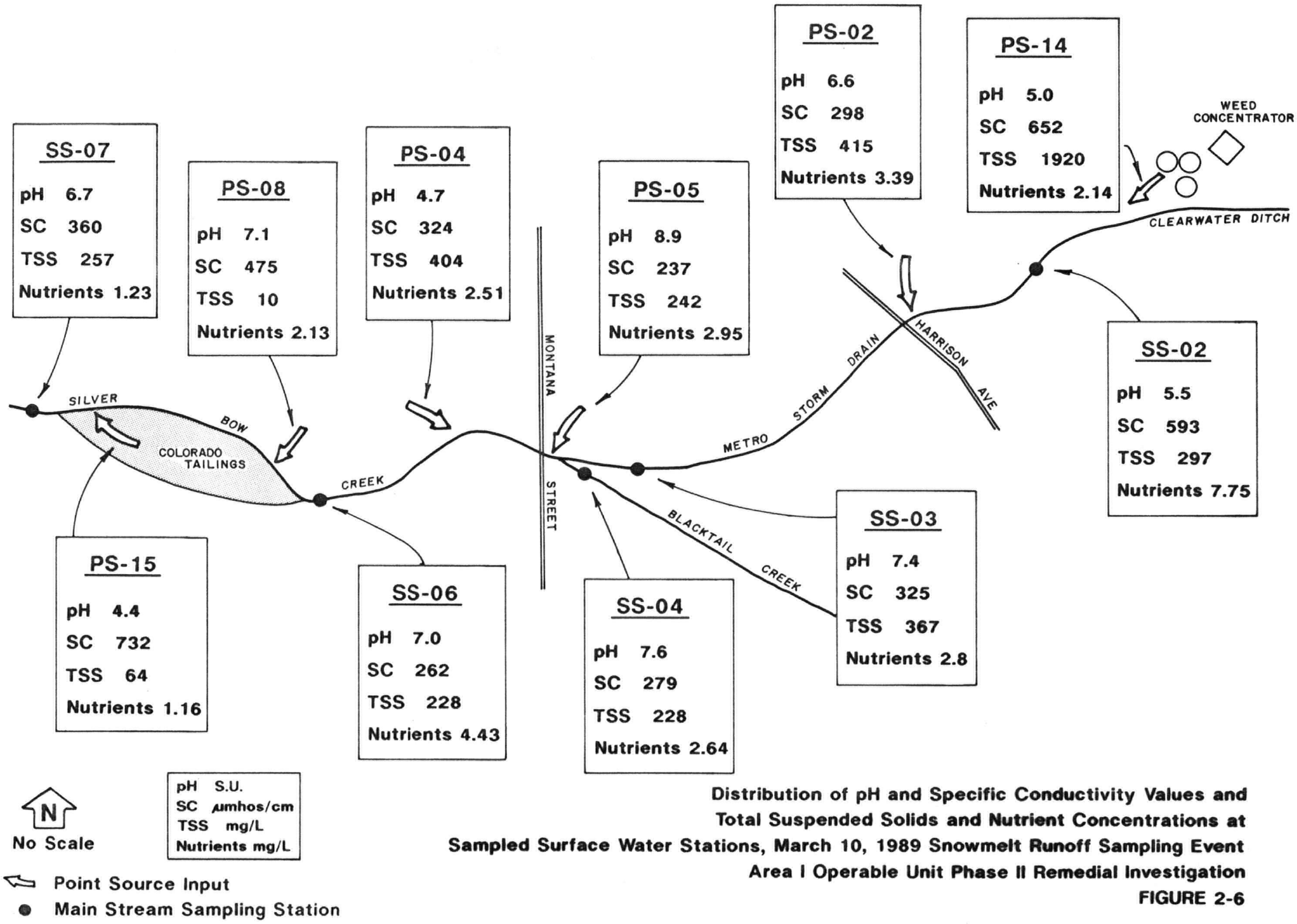
The type of water sampled in mainstem stations SS-04, SS-06, and SS-07 (Figure 2-1) did not change in a downstream direction during the snowmelt runoff event, even after the addition of different water types from several inputs along the course of Silver Bow Creek. Water at these stations remained a calcium bicarbonate type, presumably because the majority of flow in Silver Bow Creek during the runoff event was derived from Blacktail Creek.

Average values for specific conductance (SC), pH, total suspended solids (TSS) and nutrient concentrations are presented for each sampling location on Figure 2-6. Lowest pH values (5.0 s.u. or less) were measured at sampling sites monitoring runoff from the Weed Concentrator complex (PS-14); Missoula Gulch (PS-05); and the Colorado Tailings (PS-15). Mainstem sampling stations along Blacktail Creek and Silver Bow Creek indicated that pH decreased in a downstream direction during the snowmelt runoff event (7.6 s.u. at SS-04 to 6.7 s.u. at SS-07) (Figure 2-6).

Specific conductance values of samples obtained from the various surface water sampling sites monitored ranged from 237 to 732 umhos/cm @ 25° C. The largest values were measured at stations PS-14, PS-15, and SS-02 (Figure 2-6).

Total suspended solids (TSS) concentrations ranged from 10 to 1920 mg/L at sampled sites. Highest TSS concentrations occurred in water exiting the Weed Concentrator complex area (PS-14); the lowest TSS concentration occurred in discharge from the Sewage Treatment Plant (PS-08). TSS concentration in mainstem sampling stations SS-04, SS-06, and SS-07 were relatively consistent (Figure 2-6).

Nutrient concentrations (measured as nitrate + nitrite as N) ranged from 1.16 mg/L at PS-15 (runoff from the Colorado Tailings) to 7.75 mg/L at SS-02 (head of the Metro Storm



Distribution of pH and Specific Conductivity Values and Total Suspended Solids and Nutrient Concentrations at Sampled Surface Water Stations, March 10, 1989 Snowmelt Runoff Sampling Event
Area I Operable Unit Phase II Remedial Investigation
FIGURE 2-6

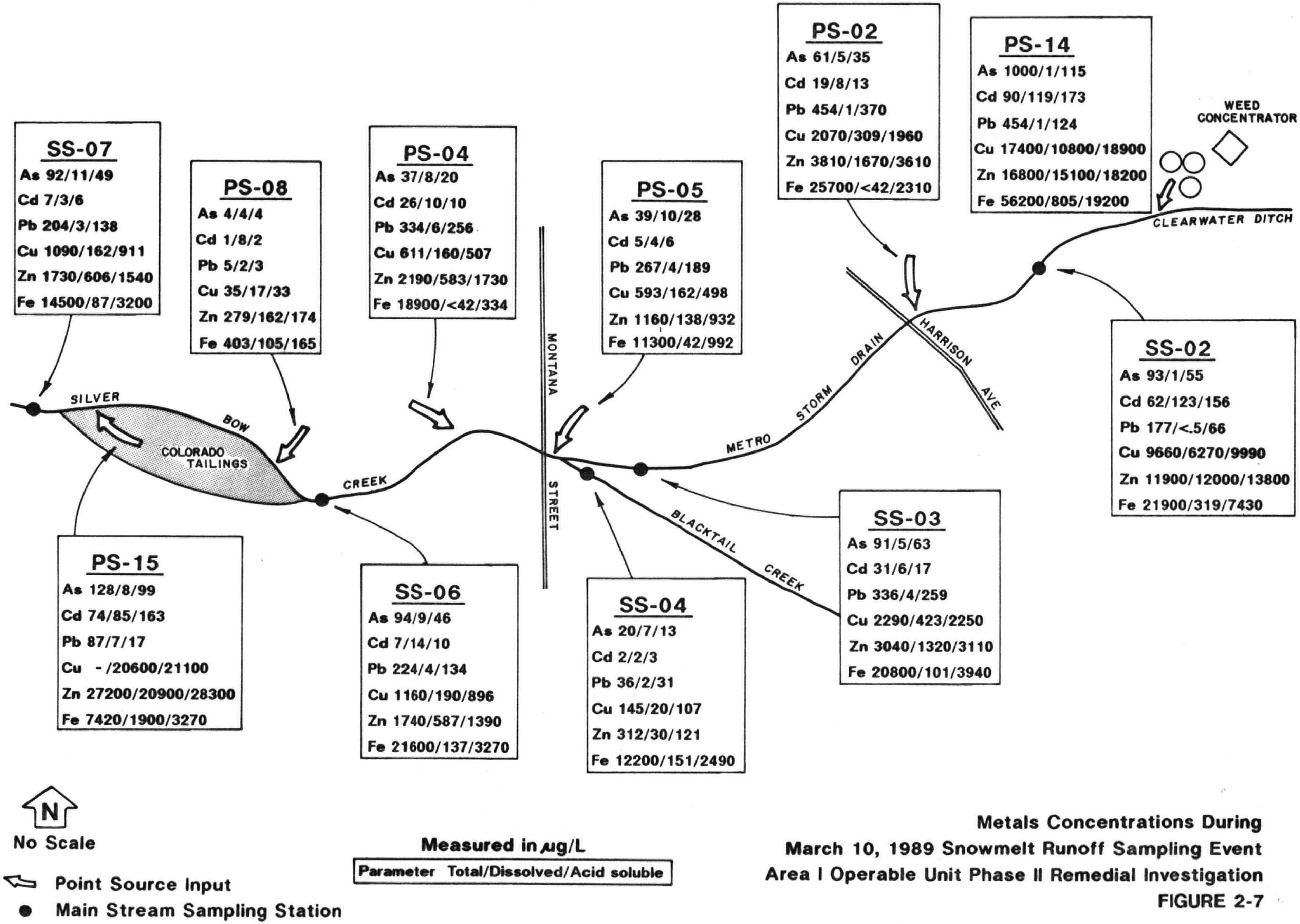
Drain) (Figure 2-6). Other monitored stations contained nutrient concentrations in the 2 to 4 mg/L range.

Figures 2-7 illustrates concentration data for total, dissolved, and acid soluble arsenic, cadmium, lead, copper, iron, and zinc for stations sampled during the snowmelt runoff event. Figure 2-8 contains plots of copper, zinc, and TSS concentrations and loadings at mainstem sampling sites SS-04 (Blacktail Creek) and SS-06 (Silver Bow Creek above the Colorado Tailings). Figure 2-9 presents loading data for total, dissolved, and acid soluble arsenic, cadmium, lead, copper, zinc, and iron for monitored stations.

Highest concentrations of total and acid soluble metals measured during the snowmelt runoff event generally occurred in water entering the Metro Storm Drain from the Weed Concentrator area (PS-14) and in runoff from the west end of the Colorado Tailings (PS-15) (Figure 2-7). The lowest measured concentrations of total and acid soluble metals occurred in discharge from Blacktail Creek and in the Sewage Treatment Plant effluent.

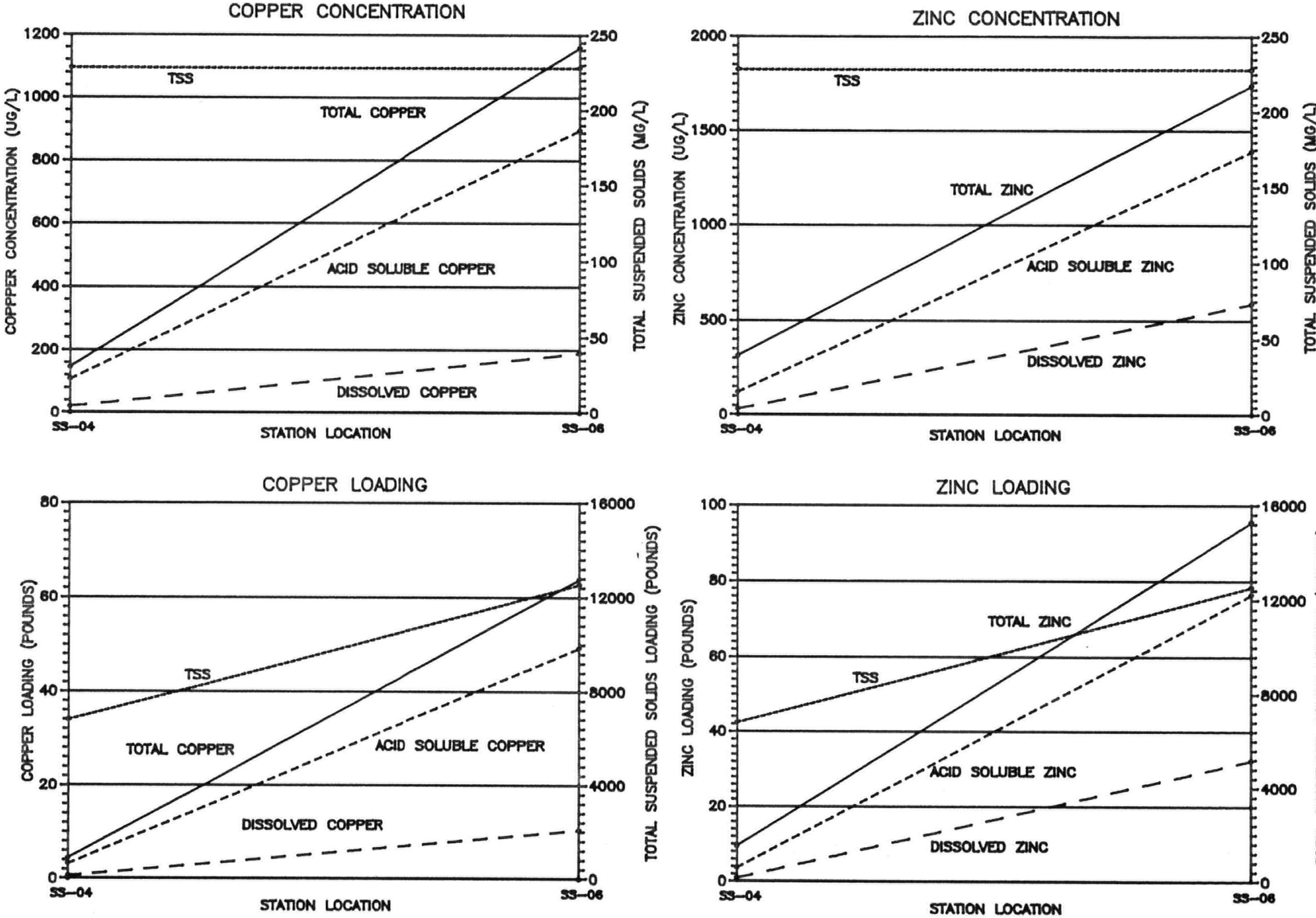
Metals data presented on Figure 2-7 suggest that arsenic, lead, and iron were generally transported through the surface water system during the snowmelt runoff event in the total fraction. Cadmium in the system during the runoff event was generally in the dissolved form. Copper and zinc were primarily carried in the dissolved fraction in the upper Metro Storm Drain area but appeared to precipitate out to the total fraction in the higher pH water in the lower Metro Storm Drain area and along Silver Bow Creek.

Total, dissolved, and acid soluble copper and zinc concentrations increased measurably between mainstem sampling sites SS-04 at the mouth of Blacktail Creek and SS-06 on Silver Bow Creek above the Colorado Tailings (Figure 2-8). TSS concentrations were generally similar between stations SS-04 and SS-06 (Figure 2-8). The primary reason for the measured increase in copper and zinc concentrations between SS-04 and SS-06 is input of metals-laden water from the Metro Storm Drain (SS-03) into Silver Bow Creek. The fact that TSS concentrations did not change significantly between the two sampling stations suggests that input concentrations of TSS from Blacktail Creek and the Metro Storm Drain and other inputs to Silver Bow Creek are relatively similar.



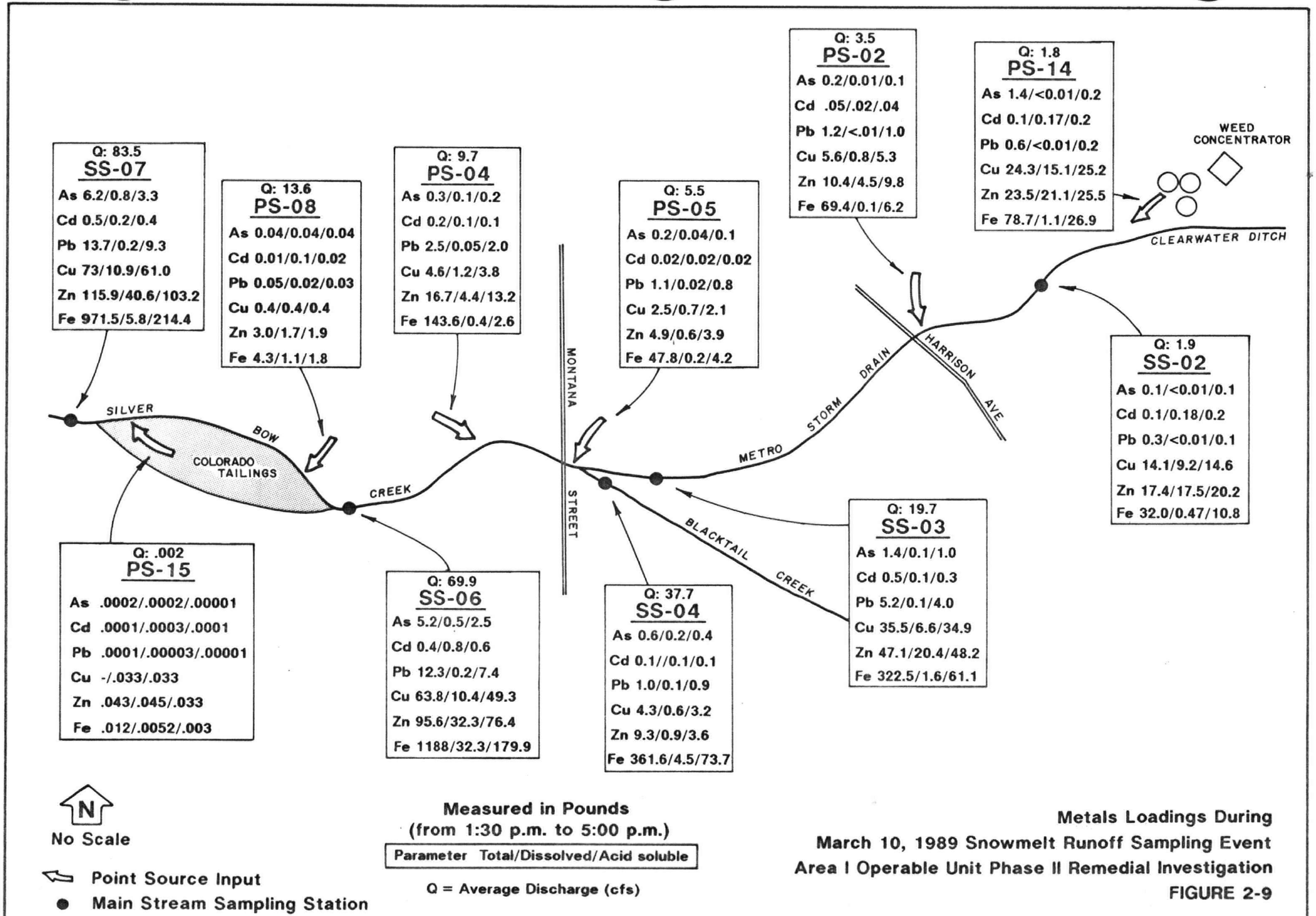
Metals Concentrations During
March 10, 1989 Snowmelt Runoff Sampling Event
Area I Operable Unit Phase II Remedial Investigation
FIGURE 2-7

Concentrations and Loads of Copper, Zinc and Total Suspended Solids at Main Stem Sampling Sites in Area I, March 10, 1989 Snowmelt Runoff Sampling Event



Area I Operable Unit Phase II Remedial Investigation

FIGURE 2-8



Metals Loadings During
March 10, 1989 Snowmelt Runoff Sampling Event
Area I Operable Unit Phase II Remedial Investigation
FIGURE 2-9

Metals loading numbers presented on Figures 2-8 and 2-9 represent the total metal-specific load which was transported by each station during a common three and one-half hour period for all stations sampled. Metal concentrations used in the loading calculations represent those measured in the composite sample collected at each sample station. Average discharge values used in the loading calculations were time weighted averages of instantaneous discharge measurements made during the snowmelt runoff event. This type of presentation of metals loads provides a means to evaluate parameter-specific loadings during a discrete time period; it does not represent the total load contributed during the entire snowmelt event.

Copper and zinc loads for total, dissolved, and acid soluble fractions and TSS increased in a downstream direction at mainstem sampling sites SS-04 and SS-06 (Figure 2-8). The rate of increase in copper and zinc loads was greatest for the total and acid soluble fractions as compared to the dissolved fractions. These trends indicate that the TSS entering Silver Bow Creek between Blacktail Creek and station SS-06, located above the Colorado Tailings contain elevated concentrations of copper and zinc as well as other metals. The primary sources of metals-laden TSS entering this reach of Silver Bow Creek include the Metro Storm Drain discharge and inputs from the Kaw Avenue storm drain and Missoula Gulch. Other unmeasured line and point source inputs may also add to the TSS concentrations entering the stream.

Figure 2-9 illustrates loads of arsenic, cadmium, lead, copper, zinc, and iron spatially at stations sampled during the snowmelt runoff event for a common time increment. In general, total metals loadings increased from the upper end of the Metro Storm Drain to below the Colorado Tailings (Figure 2-9). The largest point source load inputs to the Metro Storm Drain and Silver Bow Creek of total arsenic, copper, and zinc in the study area were derived from runoff from the Weed Concentrator area (PS-14). Missoula Gulch (PS-04) provided the greatest total lead and cadmium loads to the main stem surface water courses (2.54 pounds and 0.2 pounds, respectively).

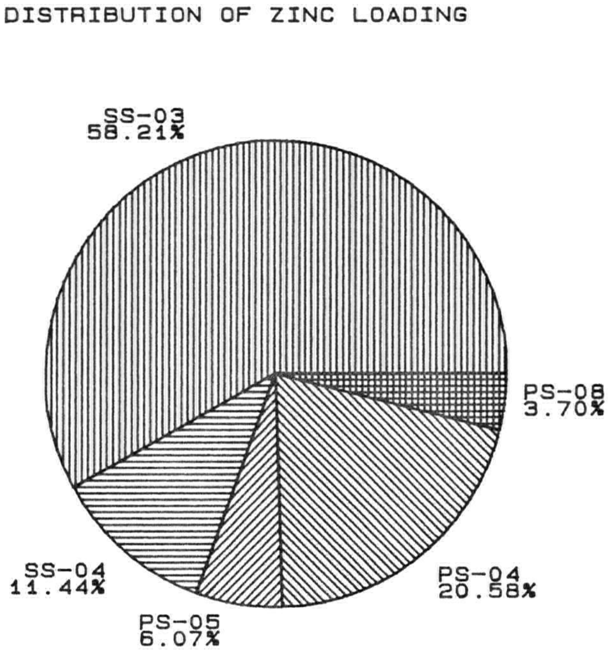
In comparing total metals loads between mainstem sampling stations SS-02, SS-03, SS-06, and SS-07, the greatest load contributions of arsenic, lead, copper, zinc, and iron occurred between stations SS-03 and SS-06 (Figure 2-9). The greatest input of total cadmium load occurred between stations SS-02 and SS-03 which includes the Metro Storm Drain. The next largest load increase of these metals was measured between stations SS-02 and SS-03, which generally bracket the Metro Storm Drain (Figure 2-9). The largest load increase of cadmium was measured between stations SS-02 and SS-03 (Figure 2-9). Acid soluble metals loads shown on Figure 2-9 exhibit these same general relationships.

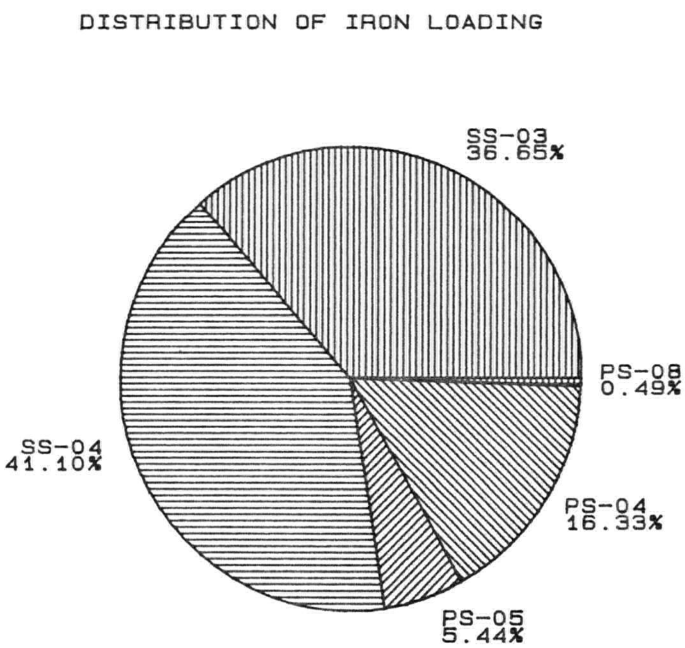
The distribution of load contribution to Silver Bow Creek during the snowmelt sampling event is shown on Figures 2-10, 2-11, and 2-12. These figures illustrate the relative distribution of total metals load as compared between sampling stations; the figures do not take into account deposition and other mass balance factors which affect sediment transport during runoff events. The illustrations indicate that relatively greater loads of total zinc, arsenic, cadmium, lead, and copper were derived from the Metro Storm Drain (SS-03) as compared to other inputs to Silver Bow Creek in Area I (Figures 2-10, 2-11, and 2-12). The majority of the iron load input to Silver Bow Creek was derived from Blacktail Creek (SS-04) and the Metro Storm Drain (SS-03) (Figure 2-10).

Analytical data indicate that numerous exceedances of both chronic and acute aquatic water quality criteria and both primary and secondary drinking water standards occurred at several stations sampled during the snowmelt runoff event in Area I. These exceedances are summarized in Table 2-3. Primary drinking water standards for arsenic, cadmium, and lead were measured at several stations sampled during the snowmelt runoff event. The most frequently exceeded aquatic water quality criteria exceedances at monitored stations were for either total or acid soluble cadmium, lead, copper and zinc.

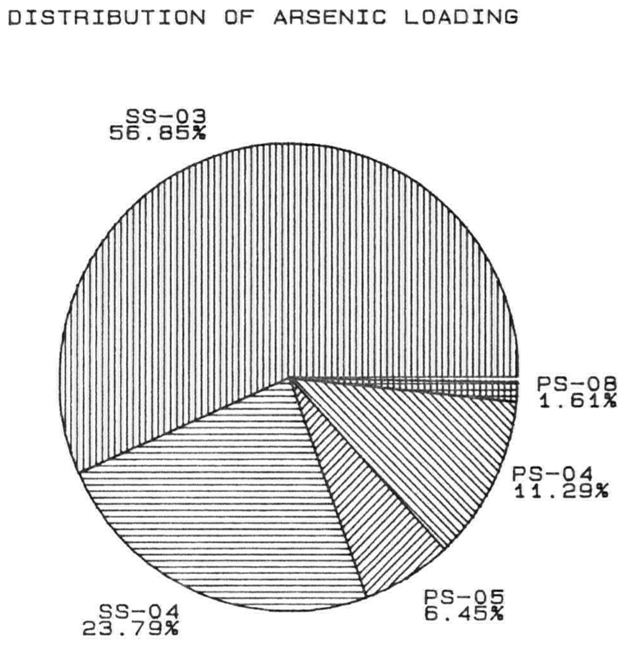
Hexavalent chromium concentrations in snowmelt runoff samples collected were all below 5 g/L, the analytical detection limit used during the analyses.

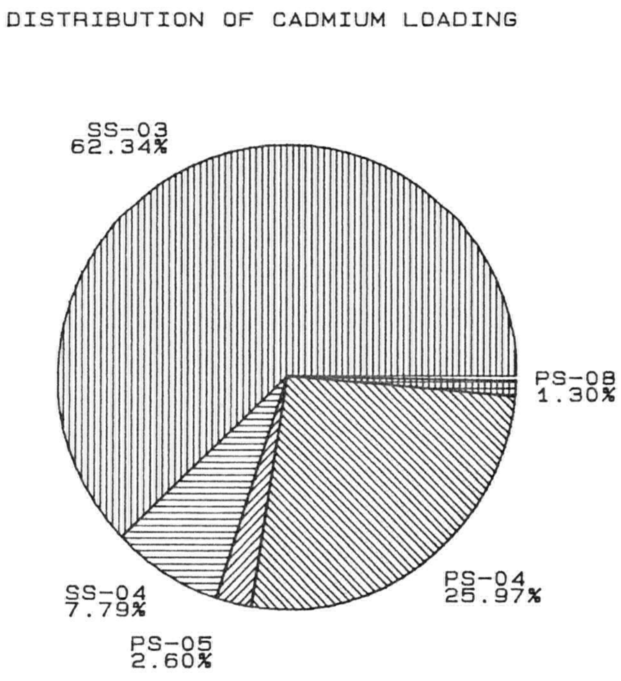
Organic data obtained during the snowmelt sampling event indicate most compounds analyzed were near or below their respective detection limits for Contract Laboratory Program Routine Analytical Services analyses. Organic compounds detected at the three stations sampled during the snowmelt runoff sampling event in Area I were primarily pesticides.





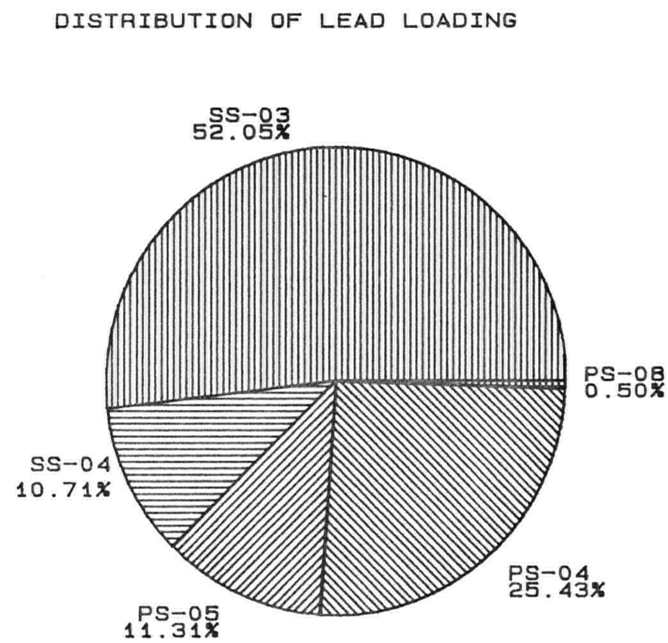
Distribution of Zinc and Iron Loadings
During March 10, 1989 Snowmelt Runoff Sampling Event
Area I Operable Unit Phase II Remedial Investigation
FIGURE 2-10

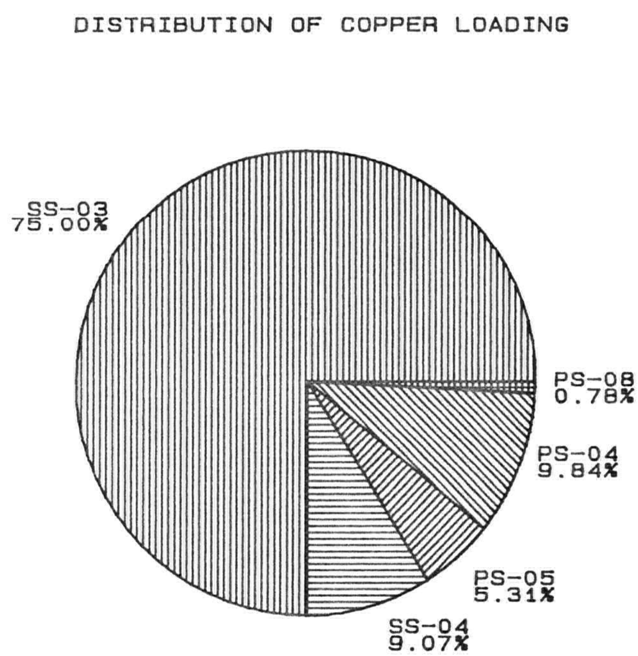




Distribution of Arsenic and Cadmium Loadings During March 10, 1989 Snowmelt Runoff Sampling Event Area I Operable Unit Phase II Remedial Investigation

FIGURE 2-11





Distribution of Lead and Copper Loadings
During March 10, 1989 Snowmelt Runoff Sampling Event
Area I Operable Unit Phase II Remedial Investigation
FIGURE 2-12

Measured concentrations of detected organic compounds in collected samples did not exceed any established drinking water standards or health advisories. The data also indicate that compounds detected in samples collected from the water surface were generally also detected in samples collected from below the water surface.

2.3.2 Low Flow Sampling Event

Low flow sampling was completed on August 21, 1989 at sampling stations SS-03, SS-04, and SS-07. The intent of sampling organic compounds during these flow conditions was to determine if sources of organic contamination derived from groundwater inflow or other sources could be identified in the area's surface water courses.

Analytical data resulting from low flow sampling completed in Area I during the Phase II Remedial Investigation indicate organic compounds detected were generally similar to those detected during the snowmelt runoff event and included mostly pesticides. Measured concentrations of detected compounds in collected samples did not exceed established drinking water standards or health advisories. The data also indicate that compounds detected in samples collected from the water surface were generally also detected in samples collected from below the water surface.

TABLE 2-3

SUMMARY OF AQUATIC AND DRINKING WATER
EXCEEDANCES; AREA I OPERABLE UNIT
MARCH 10, 1989 SNOWMELT RUNOFF EVENT

EXCEEDANCES
(Y = YES; N = NO; N/A = NOT APPLICABLE)

STATION[1]	PARAMETER	CHRONIC[2]	ACUTE[3]	MCL[4]	SMCL[5]
SS-02	As	N	N	Y	N/A
	Cd	Y	Y	Y	N/A
	Pb	Y	Y	Y	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	Y
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	Y
	Mn	N/A	N/A	N/A	Y
SS-03	As	N	N	Y	N/A
	Cd	Y	Y	Y	N/A
	Pb	Y	Y	Y	N/A
	Cr	N/A	N/A	Y	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	Y
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	N
	Mn	N/A	N/A	N/A	Y
SS-04	As	N	N	N	N/A
	Cd	Y	N	N	N/A
	Pb	Y	Y	N	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	N
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	N
	Mn	N/A	N/A	N/A	Y
SS-06	As	N	N	Y	N/A
	Cd	N	N	N	N/A
	Pb	Y	Y	Y	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	Y
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	N
	Mn	N/A	N/A	N/A	Y
SS-07	As	N	N	Y	N/A
	Cd	N	N	N	N/A
	Pb	Y	Y	Y	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	Y
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	N
	Mn	N/A	N/A	N/A	Y
PS-02	As	N	N	Y	N/A
	Cd	Y	N	Y	N/A
	Pb	Y	Y	Y	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	Y
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	N
	Mn	N/A	N/A	N/A	Y
PS-04	As	N	N	N	N/A
	Cd	Y	N	Y	N/A
	Pb	Y	Y	Y	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	N
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	N
	Mn	N/A	N/A	N/A	Y
PS-05	As	N	N	N	N/A
	Cd	N	N	N	N/A
	Pb	Y	Y	Y	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	N
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	N
	Mn	N/A	N/A	N/A	Y
PS-08	As	N	N	N	N/A
	Cd	N	N	N	N/A
	Pb	Y	N	N	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	N
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	N
	Mn	N/A	N/A	N/A	Y

TABLE 2-8 continued

STATION[1]	PARAMETER	CHRONIC[2]	ACUTE[3]	MCL[4]	SMCL[5]
PS-14	As	Y	Y	Y	N/A
	Cd	Y	Y	Y	N/A
	Pb	Y	Y	Y	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	Y
	Fe	N/A	N/A	N/A	Y
	Zn	Y	Y	N/A	Y
	Mn	N/A	N/A	N/A	Y
PS-15	As	N	N	Y	N/A
	Cd	Y	Y	Y	N/A
	Pb	Y	N	Y	N/A
	Cr	N/A	N/A	N	N/A
	Cr VI	N	N	N/A	N/A
	Cu	Y	Y	N/A	Y
	Fe	N/A	N/A	N/A	N
	Zn	Y	Y	N/A	Y
	Mn	N/A	N/A	N/A	Y

[1]Sample station locations shown on Figure 2-1.

[2]Freshwater chronic water quality criteria - hardness dependent. From U.S. EPA (1986)

[3]Freshwater acute water quality criteria - hardness dependent. From U.S. EPA (1986).

[4]Drinking water maximum contaminant level. From 40 CFR Part 141, Dec., 1975.

[5]Drinking water secondary maximum contaminant level. From 40 CFR Part 143, July, 1979.

3.0 GROUNDWATER INVESTIGATION

3.1 METHODOLOGY

This section presents brief descriptions of methodologies used to complete various components of the Phase II Remedial Investigation groundwater study. In general, study methods utilized at the site were consistent with procedures described in the project sampling and analysis plan (CH2M HILL, 1989d). Deviations to field methods described in the project sampling and analysis plan resulting from completion of the Phase II Remedial Investigation are described in Section 3.2.

3.1.1 Surface Geophysical Investigation

A surface geophysical investigation was completed in the Area I Operable Unit using a Bison Model 2390-T-50 transmitter and the Model 2390-R receiver earth resistivity system. Electrical resistivity surveying is a geophysical technique that measures apparent earth resistivity from the ground surface. Because various types of earth materials exhibit certain characteristic resistivity values, they can be distinguished from one another. Surface resistivity testing is also suited to locating groundwater and to identifying spatial changes of the specific electrical conductivity of shallow groundwater.

The objective in completing a resistivity survey in Area I was to better define lateral and vertical changes in site lithology and groundwater conditions to provide a basis for siting groundwater monitoring wells. Field crews completed the resistivity survey at several sites within Area I. At each survey site, a sounding was completed using a Wenner array. This type of array defines the spacing requirements ("A" spacing) for both current electrodes and the potential electrodes as being equi-distant from each other. Apparent resistivity measurements were initially obtained at each site using a probe spacing of one to two feet. The spacing of the probes was then expanded outward from the sounding site incrementally and measurements of apparent resistivity were obtained at each increment. Resultant field data were entered into a field book; field plots of collected data were made on logarithmic paper to determine if additional soundings were necessary at each site to fill identified data gaps or to better define trends in the data.

Figure 3-1 shows locations and orientations of resistivity sounding sites used during the Phase II Remedial Investigation. Selected locations provided for adequate spatial distribution to provide data from throughout the study area and also focused data collection in areas exhibiting anomalous data. Sounding orientations and maximum probe spacings associated with the resistivity survey were often dictated by the presence of structures and utilities.

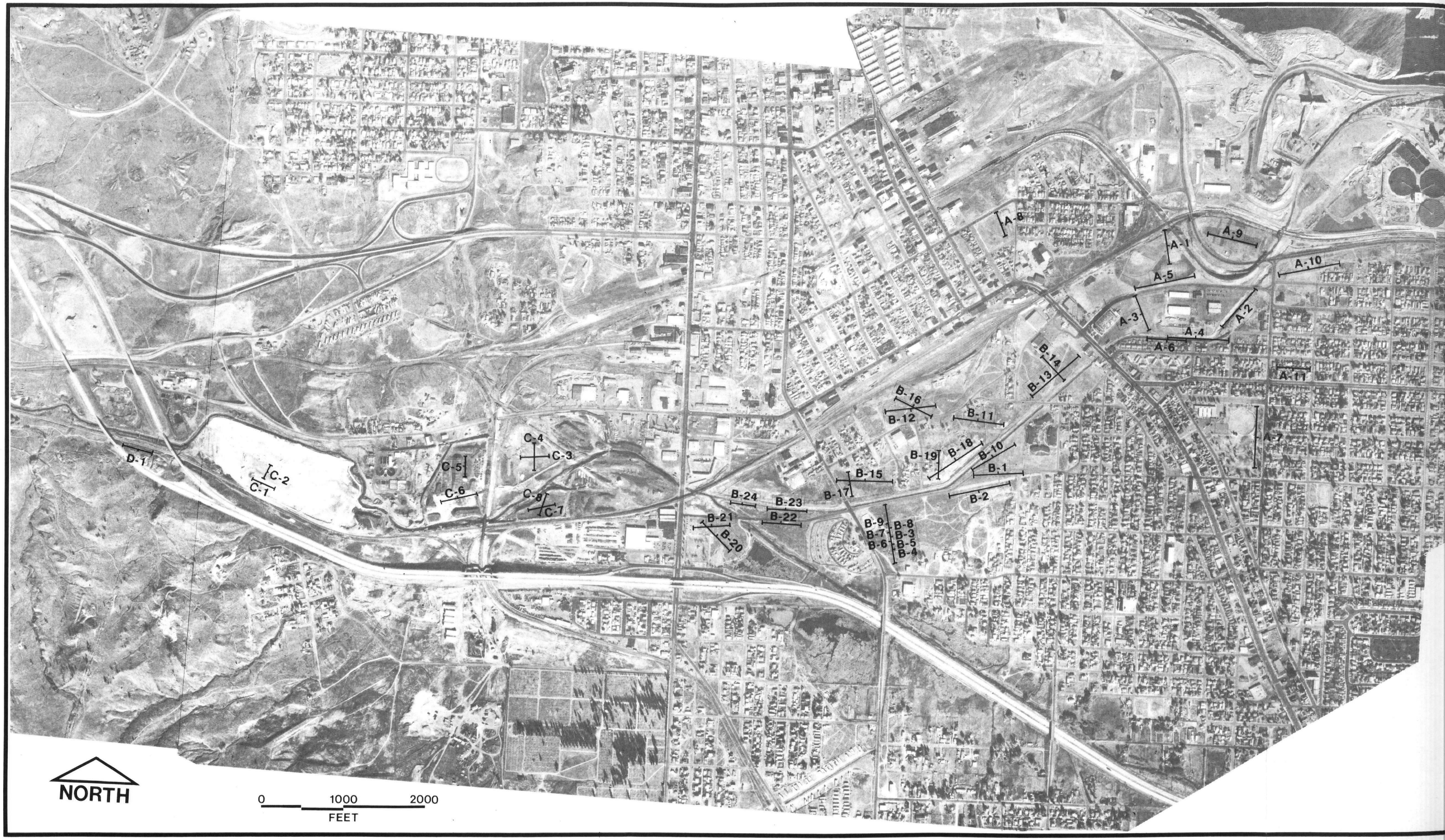
3.1.2 Monitoring Well Installation

Groundwater monitoring wells were installed at 28 locations in the Area I Operable Unit during the Phase II Remedial Investigation (Exhibit I). Paired monitoring wells were installed at 14 of the 28 well sites to determine the vertical variability of both groundwater chemistry and water levels. Paired well completions involved installation of two monitoring wells at the same site which were screened and completed at different depths.

Locations of monitoring wells installed during the Phase II Remedial Investigation were selected in consideration of the following:

- surface resistivity data,
- locations of existing monitoring wells,
- the need to collect data spatially throughout the study area,
- the need to characterize groundwater in the deep (>200 feet) groundwater-bearing units near the City-County shop complex, and
- the desire to establish cross sections of wells normal to the Metro Storm Drain and Silver Bow Creek.

Monitoring wells were installed using three types of drill rigs. These included an auger rig, a cable tool rig, and an air rotary rig. Auger drill rigs were used to install shallow monitoring wells in areas where the subsurface material was relatively easy to penetrate. This generally included the area west of Montana Street in the vicinity of the Butte



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C-1
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C-3
C-4
C-5
C-6
C-7
C-8
D-1
NORTH
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1000
2000
FEET

Locations and Orientations of Surface Resistivity Sounding Sites;
Area I Operable Unit Phase II Remedial Investigation
FIGURE 3-1

Reduction Works tailings impoundments and the Colorado Tailings. The cable tool and air rotary drill rigs were used to install deeper wells in the Colorado Tailings area and wells throughout the remainder of the site.

Monitoring wells installed during the Phase II Remedial Investigation were constructed in accordance with the following protocol:

- The drill rig and all downhole equipment were cleaned initially with a portable steam cleaner and brush.

- The borehole was then advanced. Split-spoon samples were collected periodically at zones of interest in certain boreholes. Drill cuttings were monitored continuously and described on field forms. Observations of quantities of water encountered and corresponding depths were also recorded on field forms. Samples of formation water were periodically obtained during borehole advancement and field analyzed for temperature, pH, and specific conductivity.

- Temporary steel casing with a drive shoe was advanced with the drill bit when the cable tool and air rotary drill rigs were utilized. This served to maintain borehole integrity in the unconsolidated sediments and precluded the need for drilling fluids and muds. When the auger drill rig was used, hollow-stem flight augers were advanced with the borehole to maintain borehole integrity.

- When the target depth of the borehole was achieved, decontaminated PVC casing was inserted into the borehole. Factory slotted screened sections of PVC were incorporated into the casing column adjacent to the targeted water-bearing zone.

- Chemically inert Colorado silica sand was inserted into the annular space between the temporary steel casing and the PVC casing from the total depth of the borehole to a depth several feet above the screened section of the monitoring well. An approximately one foot thick layer of quarter-inch bentonite pellets was inserted into the well annulus above the sand pack. The remaining annular space was filled with either a bentonite slurry or bentonite chips to approximately two feet below ground surface. As all of these materials were added to the well annulus, the temporary steel casing was pulled out of the borehole at a rate coincident with the volume of annular space backfilled.

The temporary steel casing was eventually pulled completely out of the borehole. Precautions were taken to make certain there was sufficient overlap between the temporary steel casing and the backfilled material to preclude gaps in the backfill sequence.

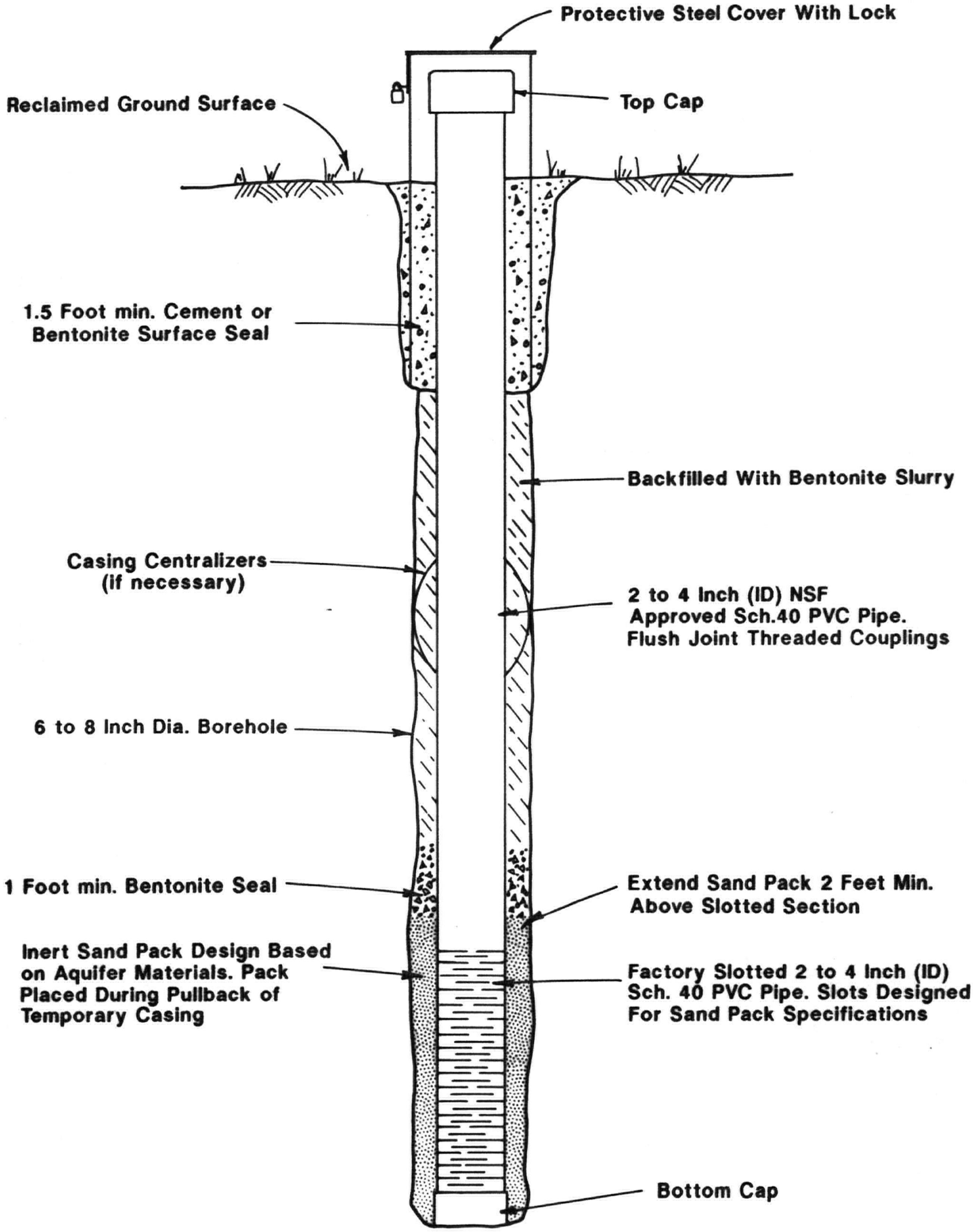
- Monitoring wells were completed by installing a locking well protector over the PVC casing. The well protector was grouted into the ground about the well to a depth of 1.5 to two feet. The well was secured with a lock after appropriate notations were made on the inside of the well protector cap denoting well number, depth, etc. Figure 3-2 is a schematic of a typical monitoring well installed during the Area I Operable Unit Phase II Remedial Investigation.

- Upon completion of monitoring well installations, each well was developed using a surge block and a hand-lift pump or bailer to remove drilling debris from the well and to insure adequate communication between the aquifer and the well. Field forms were filled out in conjunction with well development to document the status of the well during the development process.

3.1.3 Groundwater Sampling

Monitoring wells installed during the Phase I and Phase II Remedial Investigations were sampled during August and November, 1989. Several other existing monitoring wells and domestic wells were also sampled in conjunction with the August and November sampling event. Table 3-1 lists wells sampled during August and November, 1989; Exhibit I shows locations of these wells.

Monitoring wells were sampled by first evacuating at least three bore volumes from each well utilizing a decontaminated hand-lift pump in accordance with standard operating procedures described in the project sampling and analysis plan (CH2M HILL, 1989d). Field parameters including temperature, pH, and specific conductivity were monitored for



Schematic of Typical Monitoring Well Construction;
Area I Operable Unit Phase II Remedial Investigation
FIGURE 3-2

TABLE 3-1

SUMMARY OF WELLS SAMPLED DURING AUGUST AND NOVEMBER, 1989 SAMPLING EVENTS AREA I OPERABLE UNIT PHASE II REMEDIAL INVESTIGATION

Well No. [1]	Well No. [1]	Well No. [1]
AI-DW-01[2]	AI-GW-GS-22[2]	AI-GW-GS-41S[2]
AI-DW-02[2]	AI-GW-GS-23[2]	AI-GW-GS-42D[2]
AI-DW-03[3]	AI-GW-GS-24D[2]	AI-GW-GS-42S[2]
AI-GW-GS-07[2]	AI-GW-GS-24S[2]	AI-GW-GS-43D[2]
AI-GW-GS-08[2]	AI-GW-GS-25[2]	AI-GW-GS-43S[2]
AI-GW-GS-09[2]	AI-GW-GS-26[2]	AI-GW-GS-44D[2]
AI-GW-GS-10D[2]	AI-GW-GS-27D[2]	AI-GW-GS-44S[2]
AI-GW-GS-10S[2]	AI-GW-GS-27S[2]	AI-GW-GS-45[2]
AI-GW-GS-11[2]	AI-GW-GS-28[2]	AI-GW-GS-46D[2]
AI-GW-GS-12[2]	AI-GW-GS-29D[2]	AI-GW-GS-46S[2]
AI-GW-GS-13A[4]	AI-GW-GS-29S[2]	AI-GW-GS-50[2]
AI-GW-GS-13B[3]	AI-GW-GS-30D[2]	AI-PW-04[3]
AI-GW-GS-14[2]	AI-GW-GS-30S[2]	AMC - 12[3]
AI-GW-GS-15D[2]	AI-GW-GS-31D[2]	AMC - 13[2]
AI-GW-GS-15S[2]	AI-GW-GS-31S[2]	AMC - 23[3]
AI-GW-GS-16[2]	AI-GW-GS-32[2]	AMC - 24[3]
AI-GW-GS-17D[2]	AI-GW-GS-33[2]	W-01[3]
AI-GW-GS-17S[2]	AI-GW-GS-34D[2]	MP-07[3]
AI-GW-GS-18[2]	AI-GW-GS-34S[2]	MF-04[3]
AI-GW-GS-19[2]	AI-GW-GS-35D[2]	BMW-4A[3]
AI-GW-GS-20[2]	AI-GW-GS-35S[2]	BMW-4B[3]
AI-GW-GS-21D[2]	AI-GW-GS-40[2]	BMW-4T[3]
AI-GW-GW-21S[2]	AI-GW-GS-41D[2]	BMW-6B[3]
		BMW-10A[3]
		CT-84-10[3]

NOTES:

[1] Well locations shown on Exhibit I. "S" denotes shallower completion, and "D" denotes deeper completion at same site. For well AI-GW-GS-13, "A" denotes deeper completion and "B" denotes shallower completion at same site. Well Nos. AI-GW-GS-07 through AI-GW-GS-15 are Phase I RI wells. Well Nos. AI-GW-GS-16 through AI-GW-GS-50 and AI-PW-04 are Phase II RI wells.

[2] Sampled August and November, 1989

[3] Sampled November, 1989 only

[4] Sampled August, 1989 only

consistency during the evacuation process. Groundwater samples were collected following removal of at least three bore volumes of water and when measured field parameters varied by less than 5% for three consecutive measurements of evacuated water.

A decontaminated PVC bailer was then lowered into the well to obtain a sample. The extracted sample was transferred into appropriate sample containers. The sample collected for dissolved metals analysis was field filtered through a 0.45 micron filter prior to placement into the sample container in accordance with the project sampling and analysis plan (CH2M HILL, 1989d). Samples were field preserved, as appropriate, and placed into coolers. Field parameters, including temperature, pH, Eh, and specific conductivity were measured immediately upon sample retrieval and recorded on field forms.

Necessary paperwork was completed in the field in accordance with the project sampling and analysis plan. Sample coolers and corresponding paperwork were then shipped to appropriate laboratories for analysis. Table 3-2 summarizes parameters analyzed in groundwater samples collected during the August and November, 1989 sampling events.

3.1.4 Water Level Monitoring

Water levels in monitoring wells were monitored on a monthly basis in the Area I Operable Unit from August, 1989 through January, 1990. Wells included in the water level monitoring program were those wells installed during the Phase I and Phase II Remedial Investigations and selected other monitoring and domestic wells. Table 3-3 lists wells monitored for water levels within the Area I Operable Unit. Exhibit I shows locations of these wells.

Water level measurements were made with an electric well probe to a known measuring point on the well casing. The measuring point typically used during the investigation was the northern quadrant of the top of the steel well protector. The electric well probe was calibrated during each measurement episode to a steel tape. Measurements were made to the nearest hundredth of a foot and entered into a project field book. Collected data were input to the project data base management system.